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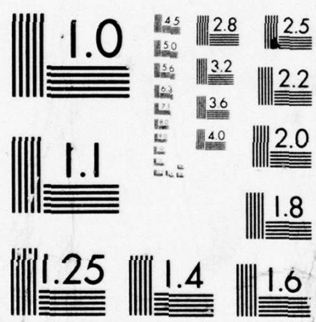

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RDT&E PROJECT NO.

USATECOM PROJECT NO. 4-6-0105-01

"PRODUCT-IMPROVEMENT TEST

OF THE

PROTOTYPE UNIVERSAL UH-1( ) PARTICLE SEPARATOR (PHASE I)"

Final Report of Test

by

CW2 Richard D. Szczepanski

7 June 1967

DEPARTMENT OF THE ARMY
UNITED STATES ARMY AVIATION TEST BOARD
Fort Rucker, Alabama 36360

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(9) Final Report of Test, 5 Jul-16 Dec 66,

~~by~~

(10) ~~CWO~~ Richard D. Szczepanski

(11) 7 June 1967

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APPROVED:

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Colonel, Artillery
President

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ABSTRACT

The US Army Aviation Test Board tested the Prototype Universal UH-1( ) Particle Separator installed in UH-1B and UH-1D Helicopters at Fort Rucker, Alabama, from 5 July 1966 to 16 December 1966. The particle separator installed in the UH-1C Helicopter was tested at Yuma, Arizona, from 18 to 27 July 1966. Testing was conducted to obtain operational experience relative to the suitability of the separator. The flight program for the UH-1B and UH-1D included hovering the helicopters in the same sandy area used in previous tests and operating the separator under field conditions such as those encountered in the Republic of Vietnam; whereas, the separator installed in the UH-1C was operated only in a sandy environment. Four deficiencies and two shortcomings were found during the test. The deficiencies were the lack of a Modification Work Order, deicing or anti-icing provisions, ice formation warning provision, and unsatisfactory adhesives for securing the rubber gaskets to metal surfaces. It was concluded that correction of the shortcomings would enhance the suitability of the particle separator and that after correction of the deficiencies, the particle separator should be suitable for Army use. It was recommended that the shortcomings be corrected as technically and economically feasible, that the separator be adopted for use on all UH-1( ) helicopters after correction of the deficiencies, and that further testing, using quantitative methods, be conducted to determine the effects of the particle separator installed in the UH-1D on short-shaft operating temperatures.

FOREWORD

The product-improvement test of the prototype Universal Particle Separator was directed by the Commanding General, US Army Test and Evaluation Command (USATECOM), in letter, AMSTE-BG, Headquarters, USATECOM, 10 June 1966, subject: "Test Directive, Product-Improvement Test, Prototype UH-1 Particle Separator."

The US Army Aviation Test Board (USAAVNTBD) was responsible for planning and conducting the test and for reporting the test results.

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SECTION 1 - INTRODUCTION

1.1. BACKGROUND.

1.1.1. As a part of the product-improvement program for the UH-1( ) helicopter, two devices--a particle separator and a barrier filter--were designed to protect the T53-L-11 engine from erosion resulting from ingested sand and dust. The USAAVNTBD conducted a comparative evaluation of these two devices installed in a UH-1D Helicopter (reference 3, appendix III, section 3). Subsequent development effort was directed toward a particle separator which would be compatible with all UH-1( ) helicopters. This effort resulted in the fabrication of the prototype Universal UH-1( ) Particle Separator. On 10 June 1966, USATECOM directed the USAAVNTBD to conduct a product-improvement test of the prototype Universal UH-1( ) Particle Separator.

1.1.2. Testing of the prototype Universal UH-1( ) Particle Separator began on 5 July 1966 with a UH-1B and UH-1D Helicopter. Additional testing was accomplished as part of the desert environmental test of the UH-1C Helicopter (reference 8, appendix III, section 3).

1.2. DESCRIPTION OF MATERIEL.

1.2.1. The prototype Universal UH-1( ) Particle Separator (figures 1 and 2) is a mechanical device designed for installation on T53 engines in UH-1B, UH-1C, and UH-1D Helicopters. It is an inertial-inlet-type separator attached to the engine-inlet housing. Engine air enters the separator radially and is redirected at a 90-degree angle into the engine-inlet housing. During this sharp turn, sand and dust particles are centrifuged into the separator chamber and are collected in the chamber after impinging against the baffle and screen assembly. A secondary airflow exists in this chamber and is directed into the engine inlet after passing through a screen assembly. The screen size is 230 mesh and is capable of retaining contaminants of a particle size as small as 80 microns.

1.2.2. In addition, each of the test helicopters was equipped with an external wire screen assembly (figures 3 and 4) designed to prevent grass and other foreign matter from entering and blocking the particle separator. The assembly was constructed of three separate wire screens. An inner screen with a mesh size of 15 squares per lineal inch was "sandwiched" between two outer screens with a mesh size of 4 squares per lineal inch. The configuration of the screen assembly was dependent upon the helicopter model. Screens were not interchangeable between the UH-1D and the UH-1B or UH-1C because of different airframe engine-inlet configurations.

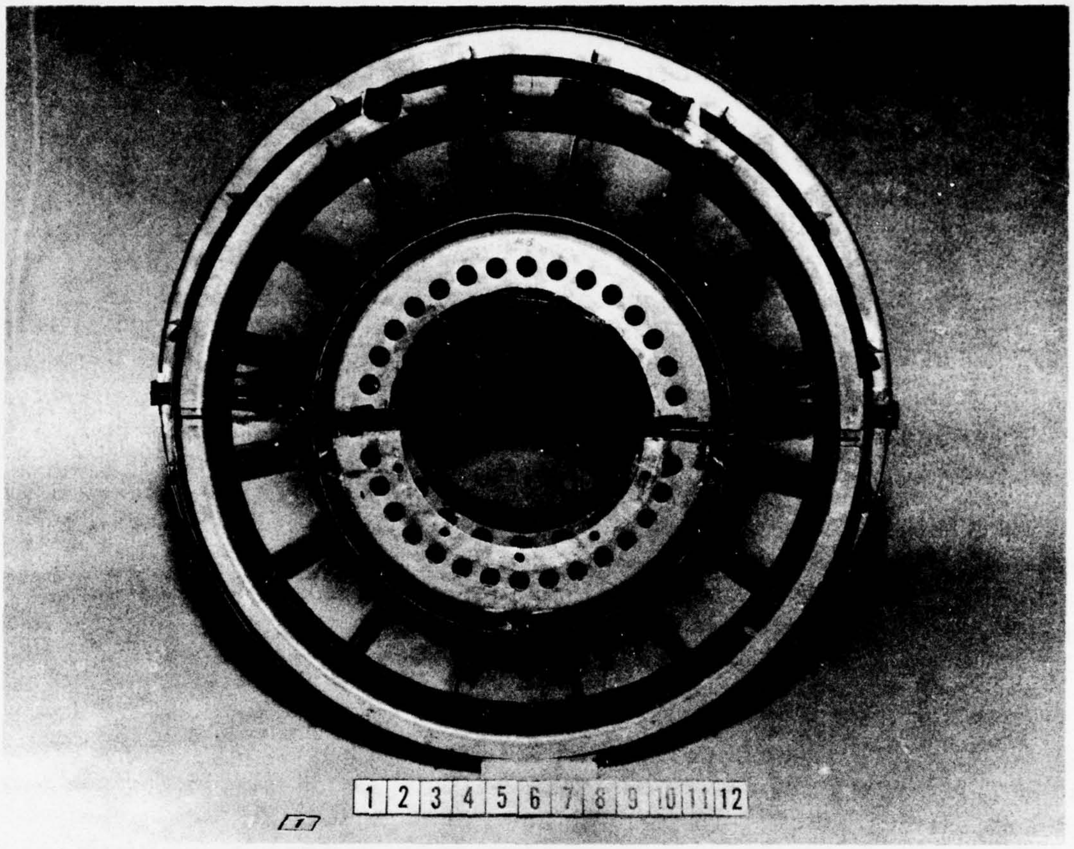


Figure 1. View of assembled particle separator (engine side).

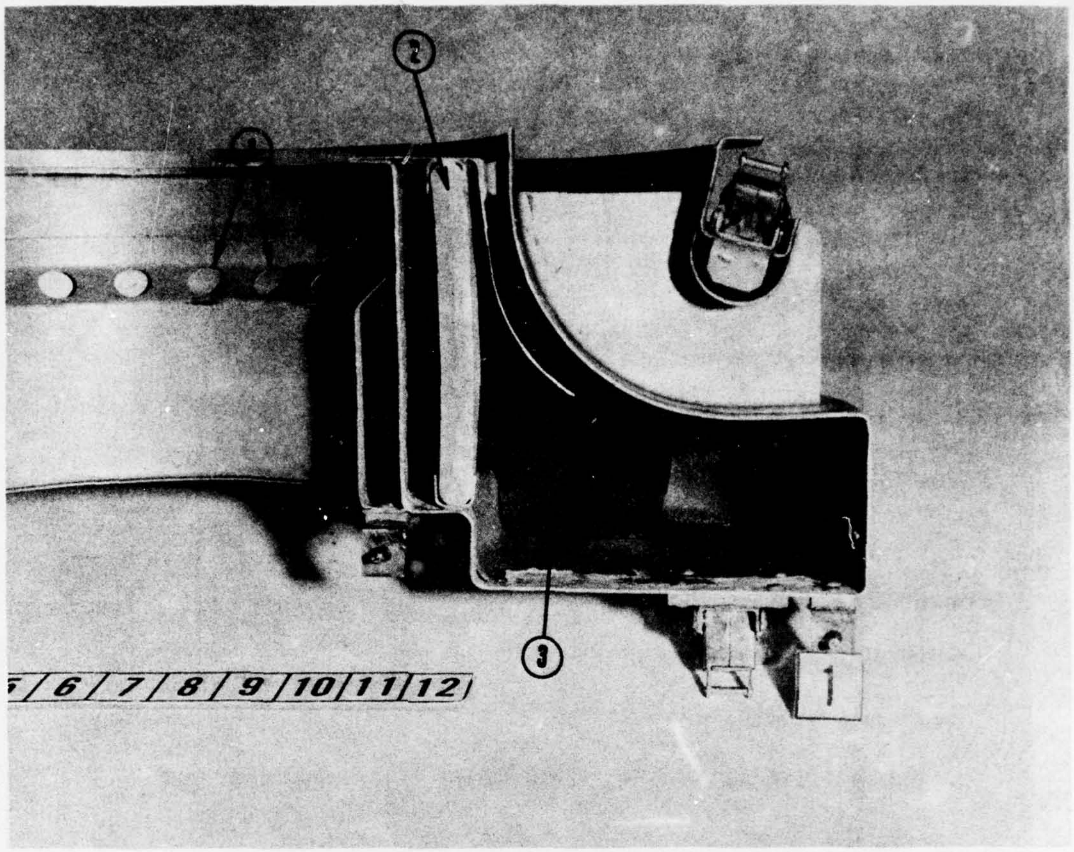


Figure 2. Top view of lower half of particle separator.

Arrow 1: Cooling air holes for short shaft.
Arrow 2: 230 mesh filler screen.
Arrow 3: Rubber cannister with porous insert.

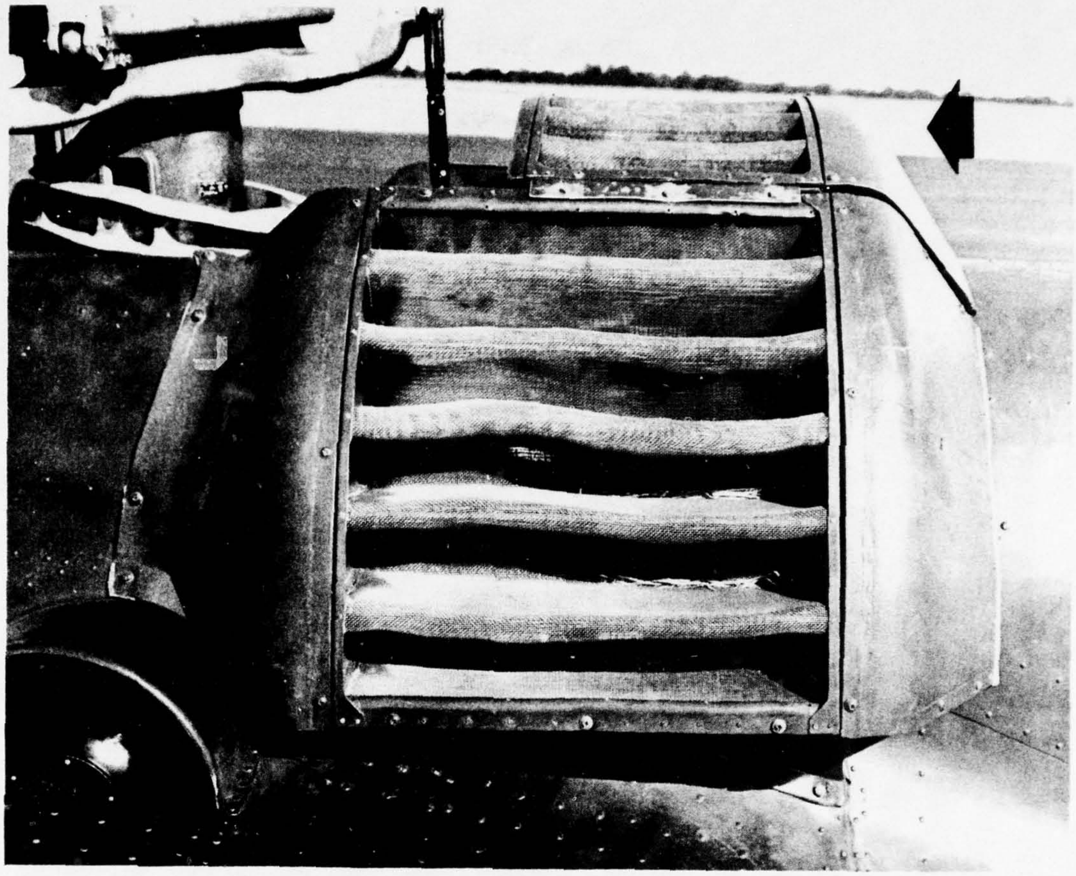


Figure 3. External screen assembly for UH-1B and UH-1C (arrow indicates front of helicopter).

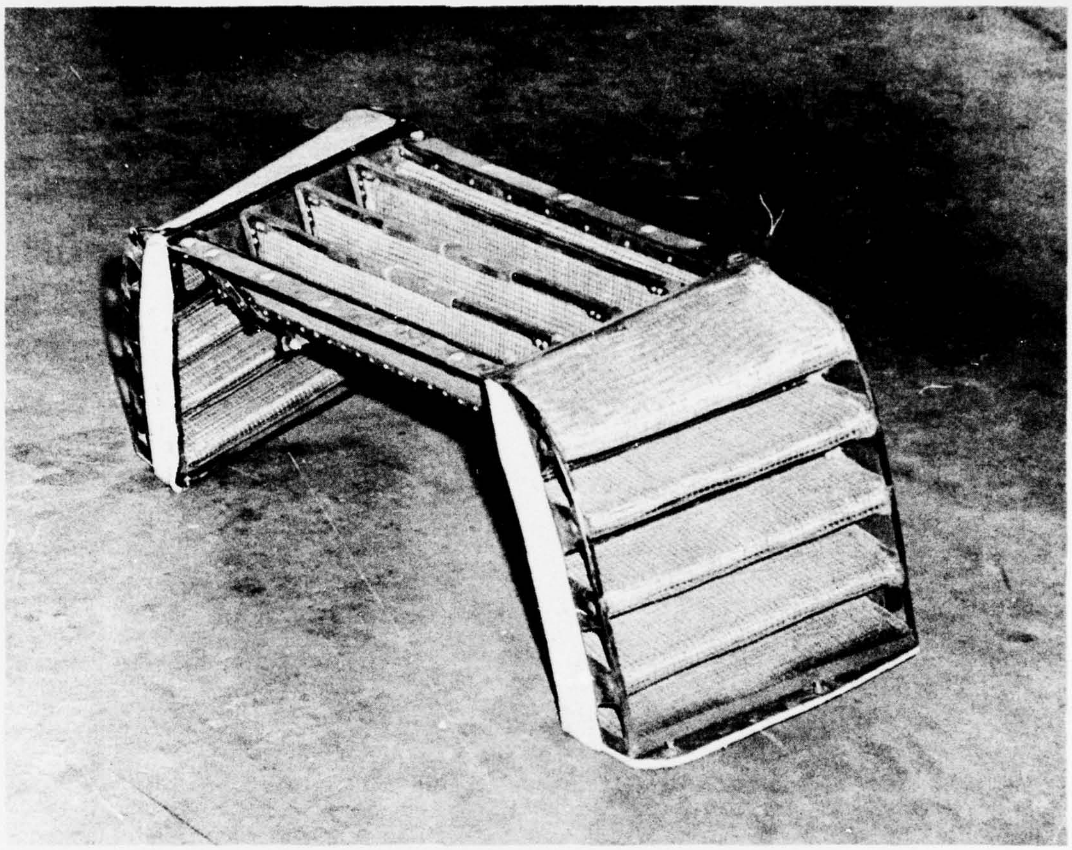


Figure 4. External screen assembly
for UH-1D.

1.3. TEST OBJECTIVES.

1.3.1. Purpose.

To develop for and provide to the Iroquois Project Manager results of operational experience relative to the suitability of the prototype Universal UH-1( ) Particle Separator installed on UH-1B, UH-1C, and UH-1D Helicopters.

1.3.2. Objectives.

To determine:

a. Adequacy of the draft modification work order (MWO).

b. Installation requirements.

c. Adequacy of draft maintenance instructions.

d. Qualitatively, the performance of the test item relative to that of the previously tested UH-1D particle separator.

e. Effects of the test item on engine-to-transmission drive shaft (short-shaft) operating temperatures.

f. Effects of rain ingestion on the performance of the test item.

g. Effects of the test item on the engine output shaft seal.

h. Frequency of and procedures for cleaning and servicing the test item.

i. Maintenance requirements.

j. Qualitatively, any problem areas encountered.

1.4. SUMMARY OF RESULTS.

1.4.1. Adequacy of Draft MWO.

A draft MWO was not furnished. The installation procedures furnished by the manufacturer were adequate, but lacked suitable illustrations depicting the configuration and emplacement of the test item.

1.4.2. Installation Requirements.

The particle separator was installed by two mechanics (MOS 67N20) on the UH-1B and UH-1C in 4.0 man-hours and on the UH-1D in 9.2 man-hours. The decrease in installation time for the UH-1B and UH-1C resulted from the same mechanics performing each installation and becoming familiar with the procedures. Installation time for the UH-1D, however, is more representative of the time which would be required to install the test item in the field.

1.4.3. Adequacy of Draft Maintenance Instructions.

The draft maintenance instructions furnished by the manufacturer were limited in scope and did not specify all possible repairs or maintenance levels.

1.4.4. Performance.

The engine erosion, power available, and surge margin checks indicated that the test item performed as well as the previously tested particle separator. However, a direct comparison of the effectiveness of the test item with that of the previously tested particle separator, based on the amount of sand collected per hour of sand exposure time, could not be made because of the variable sand concentration in the hovering area.

1.4.5. Effects on Short-Shaft Operating Temperatures.

The short-shaft operating temperatures were monitored using temperature-sensitive paint. On five occasions, temperatures in excess of the maximum allowable (280°F.) occurred on the UH-1D Helicopter and attempts to isolate the cause were unsuccessful. The particle separator, however, was suspected to be a contributing factor to the excessive temperatures. The UH-1C short shaft did not indicate temperatures in excess of the maximum at any time. The short shaft of the UH-1B Helicopter consistently operated at temperatures lower than those of the UH-1C or UH-1D.

1.4.6. Effects of Rain.

Operations in rain showers rendered the particle separator ineffective as an erosion protective device until the internal filter screens were cleaned.

1.4.7. Effects on Engine Output Shaft Seal.

There were no visible detrimental effects on the engine output shaft seal.

1.4.8. Cleaning and Servicing.

The frequency of cleaning was dependent upon the operational environment. The filter screens plugged more rapidly when the helicopter was hovered over damp sand. Because of the variable external conditions affecting the cleaning frequency, the most desirable cleaning period was during the daily inspection and immediately after flights in rain.

1.4.9. Maintenance Requirements.

The maintenance required on the test item was excessive because of the frequent replacement of gaskets. The failure of the gaskets was due to frequent removal and reinstallation of the upper portion of the test item for cleaning and the lack of an adequate adhesive to bond the gaskets to the metal surfaces of the test item.

1.4.10. Problem Areas.

1.4.10.1. The adhesive used to secure the rubber gaskets was not resistant to MIL-7808E lubricating oil and MIL-5606 hydraulic fluid and contributed to the frequent replacement of the gaskets.

1.4.10.2. There were no deicing/anti-icing capabilities for the assembly.

1.4.10.3. The Dzus-type fasteners used to secure the upper filter assembly to the engine bellmouth assembly were difficult to secure properly. One of these Dzus fasteners was a suspected source of foreign object damage (FOD) during the test. This device was replaced by a trunk latch fastener which satisfactorily corrected the problem.

1.4.11. Deficiencies and Shortcomings.

Four deficiencies and two shortcomings were discovered.

1.5. CONCLUSIONS.

1.5.1. After correction of the deficiencies listed in appendix II, section 3, the Universal UH-1( ) Particle Separator should be suitable for use on the UH-1( ) helicopters.

1.5.2. Correction of the shortcomings listed in appendix II, section 3, would enhance the suitability of the particle separator.

1.6. RECOMMENDATIONS.

It is recommended that:

1.6.1. The deficiencies listed in appendix II, section 3, be corrected.

1.6.2. The shortcomings listed in appendix II, section 3, be corrected as technically and economically feasible.

1.6.3. The Universal UH-1( ) Particle Separator be adopted for use on all UH-1( ) helicopters after correction of the deficiencies.

1.6.4. Further testing, using quantitative methods, be conducted to determine the effects of the particle separator installed in the UH-1D Helicopter on short-shaft operating temperatures.

SECTION 2 - DETAILS OF TEST

2.1. INTRODUCTION.

2.1.1. The USAAVNTBD tested the prototype Universal Particle Separator installed in UH-1B and UH-1D Helicopters at Fort Rucker, Alabama, from 5 July 1966 to 16 December 1966. The test of the particle separator installed in the UH-1C Helicopter was conducted solely at Yuma Proving Ground, Arizona, from 18 to 27 July 1966, and pertinent portions of the results of that test (reference 8, appendix III, section 3) are incorporated into this report.

2.1.2. This test consists of two basic phases--Phase I which determines the objectives listed in paragraph 1.3, section 1, and Phase II which determines the reliability of the test item and its suitability for extended operational use (reference 7, appendix III, section 3). This report covers only those objectives of Phase I.

2.1.3. Phase I.

2.1.3.1. The flight program for evaluating the particle separator installed in the UH-1B and UH-1D was designed to (1) confirm the satisfactory operation of the particle separator by hovering the helicopter in the same sandy area used in previous tests, and (2) obtain information on performance of the particle separator when operated under field conditions such as those encountered in the Republic of Vietnam (RVN). A total of 12.0 flight hours was required to accomplish the hover portion of the test with 6.5 flight hours accumulated on the UH-1B and 5.5 flight hours on the UH-1D. To accomplish the second portion of the test (RVN profiles), a total of 44.5 flight hours was required on the UH-1B and 45.9 flight hours on the UH-1D.

2.1.3.2. Throughout the test period, the amount of sand collected by the particle separator was recorded and samples were sent to the engine manufacturer for analysis.

2.1.3.3. The short-shaft operating temperatures were monitored throughout the test, but the many variables associated with the flight program tended to render the data inconclusive. (See paragraph 2.6.4.)

2.1.4. Phase II.

Phase II testing will be continued until production items are furnished for test or until further testing of the prototype particle separator is considered impractical.

2.2. DRAFT MWO.

2.2.1. Objective.

To determine the adequacy of the draft MWO for installation of the test item.

2.2.2. Method.

A draft MWO for installing the test item was not furnished; therefore, the separator was installed and removed from each helicopter in accordance with the procedures furnished by the manufacturer. The procedures were evaluated for adequacy, accuracy, and completeness, and recommended changes were recorded.

2.2.3. Results.

The manufacturer's installation procedures (part A, appendix I, section 3) were adequate for installing the particle separator. The drawing included in the procedures (figure 2-1, part A, appendix I, section 3) was a hand sketch and was difficult to interpret; however, the items could be identified after a detailed study of the drawing.

2.2.4. Analysis.

The manufacturer's installation procedures were adequate for installing the particle separator in each of the helicopters. The hand sketch in the installation procedures was not suitable for dissemination to field units.

2.3. INSTALLATION REQUIREMENTS.

2.3.1. Objective.

To determine installation requirements of the test item.

2.3.2. Method.

The test item was installed in and removed from each helicopter. The number of personnel, special tools, and time required for installation and removal were recorded.

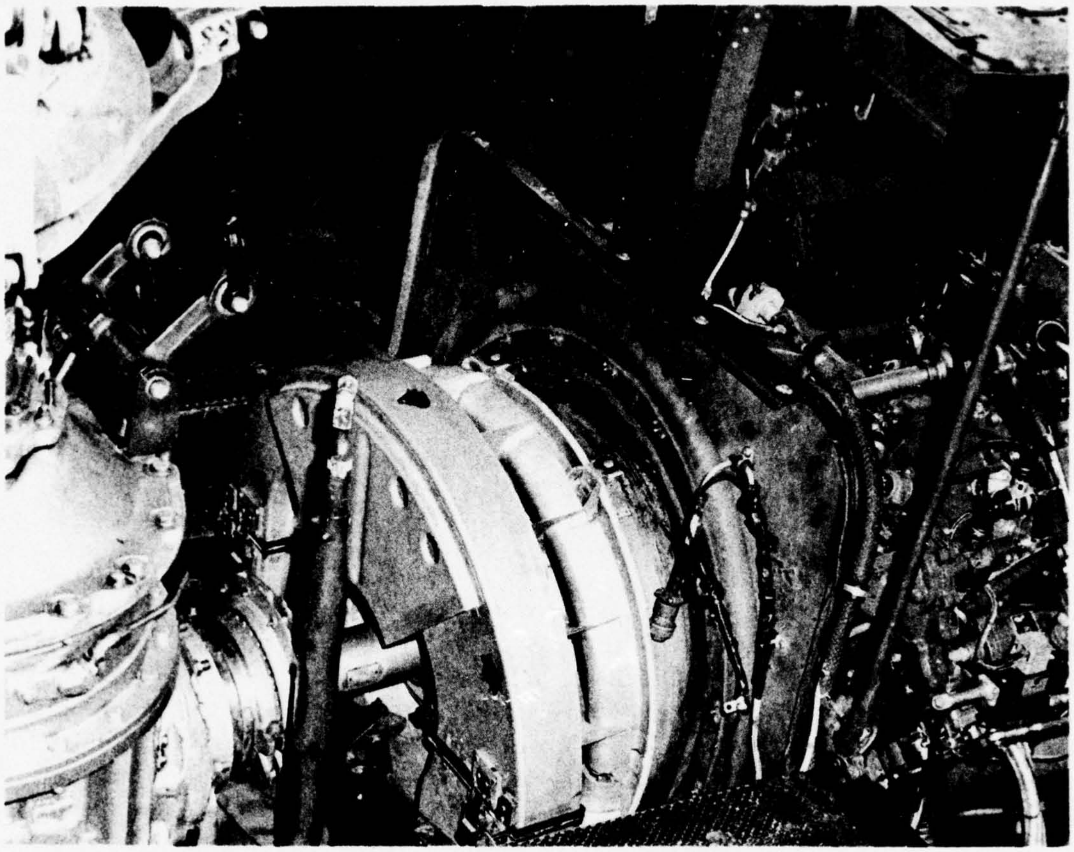


Figure 5. Particle Separator installed in UH-1D Helicopter.

2.3.3. Results.

2.3.3.1. The time required for two mechanics (MOS 67N20) to install and remove the test item was:

	Installation Time		Removal Time	
	Hours	Total Man-Hours	Hours	Total Man-Hours
UH-1B	2.0	4.0	1.6	3.2
UH-1C	2.0	4.0	1.6	3.2
UH-1D	4.6	9.2	1.5	3.0

See figure 5 for the particle separator installed in UH-1D.

2.3.3.2. The external screen assembly, which is a necessary part of the overall particle separator installation but is not a part of the particle separator per se, was installed on the UH-1D in approximately 0.1 man-hour by one mechanic (MOS 67N20). The installation of the external screen assembly on the UH-1B and UH-1C Helicopters required two mechanics (MOS 67N20) 1.0 hour for a total of 2.0 man-hours on each helicopter.

2.3.3.3. No special tools were required.

2.3.4. Analysis.

The man-hours required to install the test item are not considered excessive. The decrease in installation time for the UH-1B and UH-1C resulted from the same mechanics performing each installation and becoming familiar with the procedures. The time required to install the test item on the UH-1D is more representative of the time which which would be required to install the test item in the field.

2.4. DRAFT MAINTENANCE INSTRUCTIONS.

2.4.1. Objective.

To determine the adequacy of the draft maintenance instructions for the test item.

2.4.2. Method.

The manufacturer's draft maintenance instructions were evaluated throughout the test for accuracy, adequacy, and completeness.

2.4.3. Results.

The manufacturer's maintenance procedures (part A, appendix I, section 3) limited repairs to those of a minor nature. The only procedures furnished were for repair of the filter assembly using a special compound.

2.4.4. Analysis.

The maintenance instructions furnished by the manufacturer were unsatisfactory because of the limited scope and the recommended adhesive which was not resistant to MIL-7808E lubricating oil and MIL-5606 hydraulic fluid.

2.5. PERFORMANCE.

2.5.1. Objective.

To determine, qualitatively, the performance of the test item relative to that of the previously tested UH-1D Particle Separator.

2.5.2. Method.

A particle separator was installed in a UH-1B and UH-1D Helicopter, and each was flight tested for 25 to 50 hours at Fort Rucker, Alabama. The UH-1C (UH-1B/540 Rotor) with a particle separator installed was flown for 50 hours in the desert environment at Yuma Proving Ground, Arizona. (The method, results of test, and analysis for the UH-1C are extracts of pertinent portions of the "Product-Improvement Test (Desert Environment, CY66) of UH-1B/540 Helicopter" (reference 8, appendix III, section 3).

2.5.2.1. UH-1B and UH-1D.

2.5.2.1.1. The first series of flights was accomplished in a specially prepared sandy environment. The helicopters were hovered in the sandy environment for 30 minutes of each hour during a two-hour flight.

At the end of the two-hour flight, the test item was cleaned and the collected sand was weighed. The helicopters were flown for two flight periods in this manner to accumulate a total sand time of two hours. Using both helicopters, this particular profile was flown to determine the effectiveness of the test item to remove sand and dust from the inlet air. Its effectiveness was compared with that of the previously tested particle separator.

2.5.2.1.2. During the remaining portion of the test, the helicopters were flown in two-hour flights simulating RVN missions. Five normal to steep approaches terminating on the ground were made during each hour's flight. With the helicopters on the ground, the collective pitch was lowered to the minimum position for approximately 10 seconds. Before each takeoff, the helicopters were stabilized at a two-foot hover, then normal to maximum performance takeoffs were conducted. Time spent in the sandy environment was recorded. Cruise flight was performed at 90 knots at an absolute altitude of 1,000 to 3,000 feet. The engine was visually inspected at the end of the test to determine the degree of internal damage resulting from sand erosion and FOD.

2.5.2.2. UH-1C. The test helicopter was flown for 50 hours in the desert environment. A sufficient number of landings was made to average a landing for every 15 minutes of flight, and actual hovering time in a sandy environment was recorded. The landings were made in a variety of areas to assure use of a cross section of desert landing surfaces. Flights were conducted at various takeoff gross weights up to 9,100 pounds and during ambient temperatures up to 115°F. The operational capability of the test helicopter in the desert environment was evaluated qualitatively. A five-point engine power check (calibration) and a surge margin check were made daily to determine engine deterioration and the effectiveness of the engine-inlet particle separator. The engine was visually inspected upon completion of the test to determine the degree of internal damage resulting from sand erosion and FOD.

2.5.3. Results.

A series of charts and graphs, containing referred engine performance curves of shaft horsepower and EGT versas gas-producer speed, are contained in part C, appendix I, section 3. Engine compressor blade weight comparisons and engine measurements are contained in part D, appendix I, section 3. See part E, appendix I, section 3, for erosion effects on engine compressor components.

2.5.3.1. UH-1D.

2.5.3.1.1. The hover portion of the evaluation was accomplished at a gross weight of 8,600 pounds. Engine performance and surge margin data were collected before and after each flight. There was no reduction in surge margin after the two hours of hovering in the sand. The engine power checks showed a slight increase in available horsepower after the first hour of hovering. After the second hour, a decrease of approximately 2.6 percent of available power (22 shaft horsepower (s. hp.)) was noted. The particle separator collected a total of 5.4 pounds (2,457 grams) of sand during the 2.0 hours of hovering in the sandy environment.

2.5.3.1.2. During the RVN profile portion of the flight evaluation, the helicopter was flown for 45.9 hours during a total of 31 flights. The total amount of time spent hovering in the sandy environment was 1.8 hours. The particle separator collected a total of 7.4 pounds (3,342 grams) of sand during these flights. The engine maximum power checks performed during each flight showed no apparent decrease in helicopter performance attributable to engine erosion. During the last flight of the evaluation, engine surging was noticed on decelerations. The inspection of the engine at the end of the test showed that major FOD had occurred in the compressor section of the engine. (See paragraph 2.11.3.3.)

2.5.3.2. UH-1B.

2.5.3.2.1. The hover portion of the evaluation was accomplished at a gross weight of 8,500 pounds. Engine performance and surge margin data collected before and after each flight showed no appreciable change in engine horsepower during the flights. A total of 1.35 pounds (613 grams) of sand was collected in the particle separator during the two-hour hover period in the sandy area.

2.5.3.2.2. During the RVN profile portion of the flight evaluation, the helicopter was flown for 42.4 hours during a total of 23 flights. These flights varied from 0.5 hour to 3.0 hours in duration. The amount of time spent in the sandy environment during each landing totaled 1.6 hours for the entire period. The amount of sand collected totaled 3.5 pounds (1,581 grams). There was no noticeable decrease in helicopter performance which could be attributed to engine power loss caused by erosion.

2.5.3.3. UH-1C.

2.5.3.3.1. Evaluation of flight characteristics at gross weights of 7,000 to 9,100 pounds disclosed no unusual problems attributable to desert operations.

2.5.3.3.2. During the 50 hours of environmental testing, 200 landings and takeoffs were accomplished from unimproved desert terrain, and a total of 1.7 hours of sand hovering time was accumulated. A total of 7.6 pounds (3,474 grams) of sand was taken from the particle separator during daily cleanings. A portion of the upper and lower halves of the universal particle separator did not close together when latched. Test-cell engine calibrations performed by the manufacturer showed noticeable degradation in engine performance; however, daily power checks and qualitative evaluation of helicopter performance indicated that the degradation was negligible. The increase in exhaust gas temperature (EGT) during the test was the primary indication that some engine erosion was occurring. The results of daily surge margin checks were normal throughout the test, and the test-cell calibration showed that the engine met the surge margin requirement for a new engine. Visual inspection of the engine disclosed no FOD and only slight erosion in the compressor section. Erosion was most noticeable in the turbine area where the blade-tip clearances of the gas-producer turbine showed considerable increases.

2.5.4. Analysis.

2.5.4.1. The slight increase in engine power which occurred after the first hour of hovering in the sandy area on the UH-1D Helicopter was attributed to the increase in efficiency of the compressor section of the engine. The small particles of dust which were not trapped by the particle separator passed through the engine and polished the blades of the compressor.

2.5.4.2. The UH-1C (modified UH-1B/540) helicopter was suitable for operation in a desert environment. The engine particle separator (ECP UH-1B-275) retarded engine erosion significantly and greatly enhanced the ability of the helicopter to operate in the desert environment.

2.5.4.3. A direct comparison of effectiveness of the test item with the previously tested particle separator based on the amount of sand collected per hour of sand exposure time could not be made because of the variable

sand concentration in the hovering area. A comparison of the erosion damage and power loss in the engine indicated that the test item performed as well as the previously tested particle separator.

2.6. SHORT-SHAFT OPERATING TEMPERATURES.

2.6.1. Objective.

To determine the effects of the test item on short-shaft operating temperatures.

2.6.2. Method.

2.6.2.1. A temperature-sensitive paint was applied to the short shaft of each of the test helicopters and inspected after each flight. The temperature-sensitive paint had seven different ranges: 176°F., 203°F., 230°F., 284°F., 329°F., 347°F., and 428°F. Each of the paints used contained a pigment which would change color after its specified temperature was exceeded. A color change of the 230°F. paint would indicate that the temperature exceeded 230°F. If there were no changes in color of the next higher temperature paint (284°F.), the maximum temperature of the short shaft could have reached any temperature up to 284°F. and still indicate only 230°F. In addition, the pigment was also time sensitive. A comparatively large increase in temperature above the sensing level of the pigment for a short period of time gave the same color change as a much smaller temperature increase over a longer period. Exact temperatures, therefore, could not be determined.

2.5.2.2. A series of flights were conducted on the UH-1D Helicopter with the particle separator installed and with it removed from the helicopter. On these flights, the helicopter was ballasted to 8,600 pounds gross weight and flown at 1,000 feet pressure altitude at 100 knots indicated airspeed (IAS). The helicopter was then banked 20 consecutive times at an angle of 45 degrees for approximately 30 seconds. The helicopter was then landed and the short-shaft temperatures recorded.

2.6.3. Results.

2.6.3.1. The maximum allowable temperature limit established during the test was 280°F. At temperatures above 280°F., the lubricant in the short shaft started to degrade even though the short shaft itself suffered no apparent damage.

2.6.3.2. On the UH-1B Helicopter, there was no detectable increase in operating temperature of the short shaft with the particle separator installed. The minimum temperature detectable was 176°F., which was not attained during the test.

2.6.3.3. On the UH-1D Helicopter, the operating temperature of the short shaft was determined to be between 203°F. and 230°F. with the particle separator installed. Throughout the test program, the minimum operating temperature was 203°F. The operating temperature exceeded 280°F. on five occasions during flights while conducting the RVN profile portion of the evaluation. The maximum temperature reached was in excess of 347°F., but less than 428°F. The short-shaft over-temperatures occurred during similar flights and at comparable ambient temperatures to other flights during the evaluation.

2.5.3.4. With the intention of isolating the cause of the over-temperatures on the UH-1D Helicopter, a series of flights was made. The average operating temperature of the short-shaft remained at 203°F. to 230°F. throughout the eight hours of flight with the particle separator installed. A check of the short-shaft operating temperature with the particle separator removed showed an operating temperature of 176°F. to 203°F. when the helicopter was flown in the same maneuvers.

2.6.4. Analysis.

There were no over-temperatures (above 280°F.) of the short shaft on either the UH-1B or the UH-1C Helicopter. The average operating temperature on the UH-1C (230°F.) was higher than that on the UH-1B (below 176°F.). Over-temperatures of the short shaft occurred on the UH-1D Helicopter five times, and attempts to determine the specific cause of the condition were unsuccessful. The factors which affected short-shaft operating temperatures were vibration level, engine-to-transmission alignment, ambient temperatures, gross weight, in-flight maneuvers, and airflow. An attempt was made to induce an over-temperature of the short shaft on a series of flights made with the particle separator removed after the conclusion of the RVN profiles, but the variables mentioned obscured the validity of the results. The UH-1D Helicopter, however, operated at considerable lower short-shaft temperatures when the particle separator was removed. The particle separator was suspected to be a contributing factor to the over-temperatures experienced.

2.7. RAIN INGESTION.

2.7.1. Objective.

To determine the effects of rain ingestion on the performance of the test item.

2.7.2. Method.

The helicopter was flown twice into a rain shower for a minimum of five minutes' duration for each flight. The flights into the showers were accomplished between the first and second hour of a programmed two-hour flight. Five landings were made prior to the flight in rain and five landings were made after the flight to insure sufficient exposure to sand and dust before and after exposure to rain. After the helicopter was landed, the test item was visually inspected for effects of rain.

2.7.3. Results.

The water ingested through the particle separator collected in the rubber cannisters and reduced their effective volume by more than one half. In addition, moisture remained on the inlet filter screens and, when further exposed to sand and dust during the second hour, the dust which collected on the screens turned to mud (figure 6), restricting the secondary air circulation in the test item.

2.7.4. Analysis.

Flights in rain showers rendered the test item ineffective as an erosion protective device until it had been cleaned.

2.8. ENGINE-OUTPUT SHAFT SEAL.

2.8.1. Objective.

To determine the effects of the test item on the engine-output shaft seal.

2.8.2. Method.

Throughout the test, the engine-output shaft seal was periodically inspected for leaks or seepage. Maintenance requirements and oil consumption were noted and recorded.

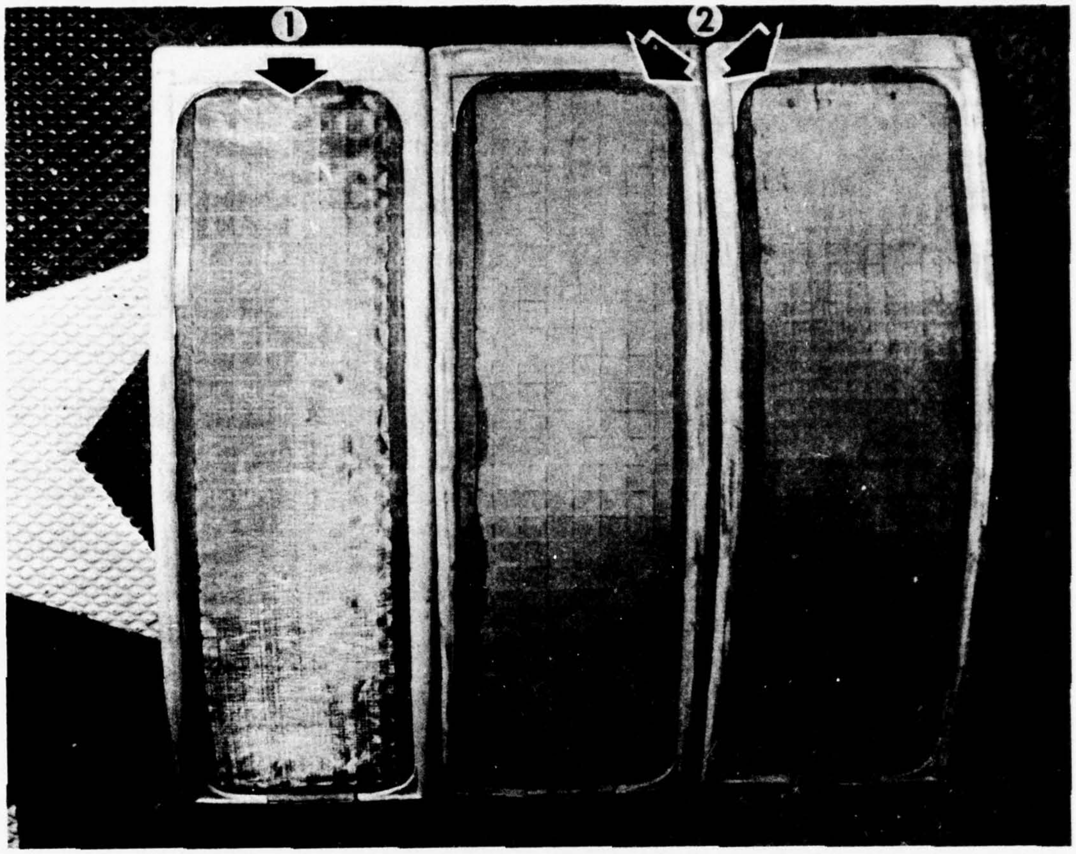


Figure 6. Internal filter screens (230 mesh).
Arrow 1: Screen before exposure to sand and dust.
Arrow 2: Screens after exposure to sand, dust, and rain.

2.8.3. Results.

There were no leaks of the engine-output shaft seal.

2.8.4. Analysis.

Not applicable.

2.9. CLEANING AND SERVICING.

2.9.1. Objective.

To determine the frequency of and procedures for cleaning and servicing the test item.

2.9.2. Method.

Throughout the test, the cleaning and servicing of the test item were monitored and data were recorded.

2.9.3. Results.

2.9.3.1. The test item required cleaning immediately after flights in rain because the upper and lower filter screens became plugged with mud. A series of flights conducted with landings in damp sand and dust also caused some plugging of the screens even though visible moisture was not present in the air.

2.9.3.2. The porous inserts used in the rubber cannisters to retain the collected dust decreased the available retaining volume of the cannisters by one half after flights in the rain (figure 7). After 11 flights the inserts were removed. There was no noticeable effect on the performance of the separator and the time required to clean the separator was reduced.

2.9.3.3. When operated in dry, sandy areas, the test item functioned for a maximum of 20.9 flight hours with 41.8 minutes of sand hover time. During this period, the test item collected approximately 3.4 pounds (1,537 grams) of sand and dust. At the end of 20.9 flight hours, the filter screens were inspected and were found to be plugged. There was no servicing required other than cleaning the filter screens and emptying the rubber cannisters.

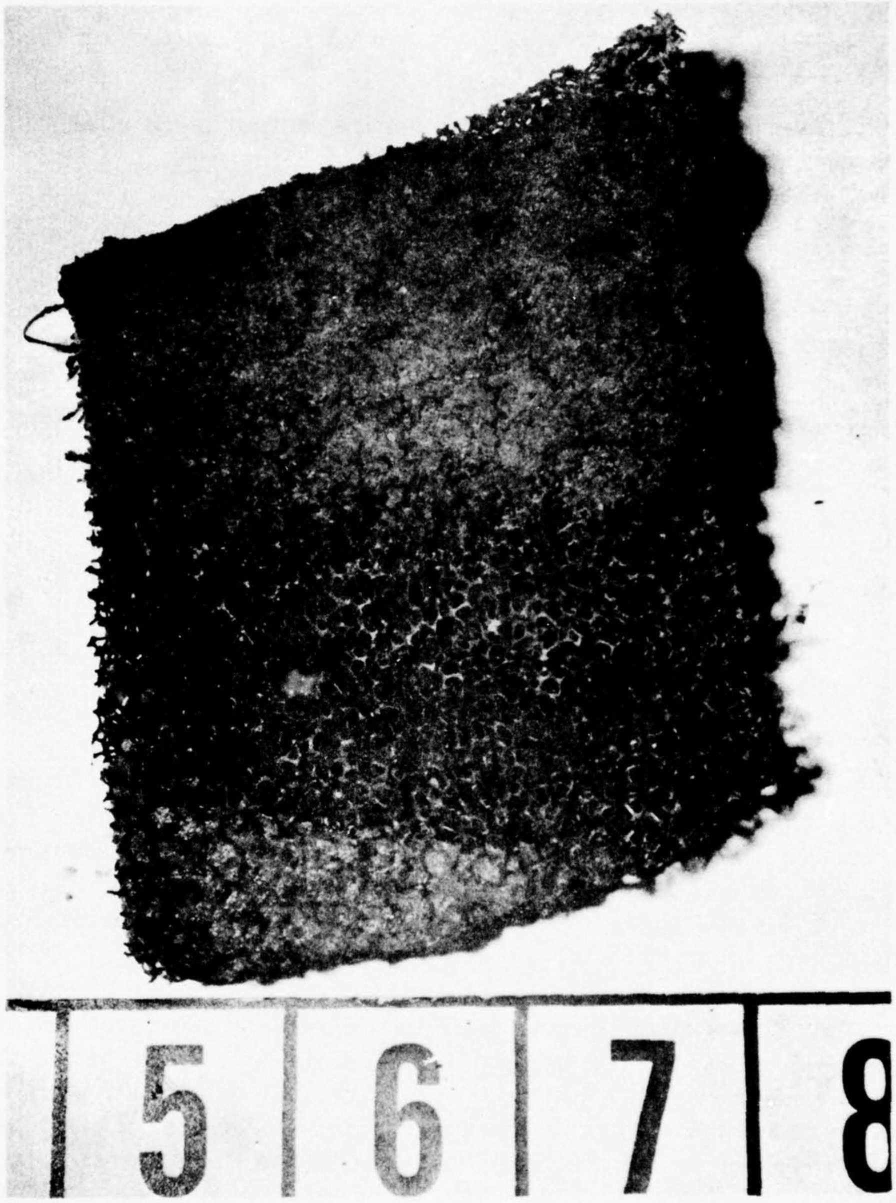


Figure 7. Porous insert
for collecting dust.

2.9.4. Analysis.

The frequency of cleaning was dependent upon the operational environment. The filter screens plugged more rapidly when the helicopter was hovered over damp sand. Because of the variable external conditions affecting the cleaning frequency, the most desirable cleaning period was during the daily inspection and immediately after flights in rain.

2.10. MAINTENANCE REQUIREMENTS.

2.10.1. Objective.

To determine maintenance requirements.

2.10.2. Method.

The test items installed in the UH-1( ) helicopters were maintained in accordance with the manufacturer's maintenance procedures (part A, appendix I, section 3). Personnel, man-hours, and special tools required to maintain the test item were recorded.

2.10.3. Results.

Maintenance of the test item was accomplished by military personnel (MOS 67N20) and required 9.7 man-hours during the period. Of this time, 9.0 man-hours were required to replace unserviceable gaskets on the test item. The adhesive used to bond the gaskets to the metal surfaces of the test item failed to adhere after 17.3 flight hours. The manufacturer then furnished two different adhesives which also failed to adhere properly after similar periods. A list of parts replaced and repairs made to the test item installed on the UH-1B and UH-1D is contained in part B, appendix I, section 3. No special tools were required for maintaining the test item.

2.10.4. Analysis.

The maintenance required on the test item was excessive because of the frequent replacement of gaskets. The failure of the gaskets was due to frequent removal and reinstallation of the upper portion of the test item for cleaning and the lack of an adequate adhesive to bond the gaskets to the metal surfaces of the test item.

2.11. PROBLEM AREAS.

2.11.1. Objective.

To determine, qualitatively, any problem areas encountered.

2.11.2. Method.

All problem areas and potential deficiencies or shortcomings were noted and recorded.

2.11.3. Results.

2.11.3.1. None of the helicopters equipped with the test item possessed an effective inlet-air anti-icing capability. Flights during icing conditions could cause ice formation on the inlet screens which would remain undetected and unremovable during flight.

2.11.3.2. The foam-rubber strips used as seals between various sections of the particle separator became unserviceable after exposure to MIL-7808E lubricating oil and/or MIL-5606 hydraulic fluid. The MIL-7808E lubricating oil loosened each of the three adhesives used to bond the foam-rubber strips to the metal surfaces of the test item (figures 8 and 9). The following adhesives were used:

a. General Electric Type RTV.

b. Dow-Corning Type RTV-731.

c. Minnesota Mining and Manufacturing Type XXX.

2.11.3.3. The Dzus fasteners located on the upper air-filter assembly were a suspected source of FOD during the test. These fasteners were replaced by trunk latches similar to the type used to secure the upper filter assembly to the lower filter assembly.

2.11.4. Analysis.

2.11.4.1. The lack of an engine-inlet ice-detection system on the external filter screen and on the test item itself would prevent safe flight during icing conditions.

2.11.4.2. The adhesives used to secure the foam-rubber gaskets were not resistant to MIL-7808E lubricating oil or MIL-5606 hydraulic fluid and were unsatisfactory.

2.11.4.3. Changing from Dzus fasteners to trunk latches on the test item eliminated a likely source of FOD.

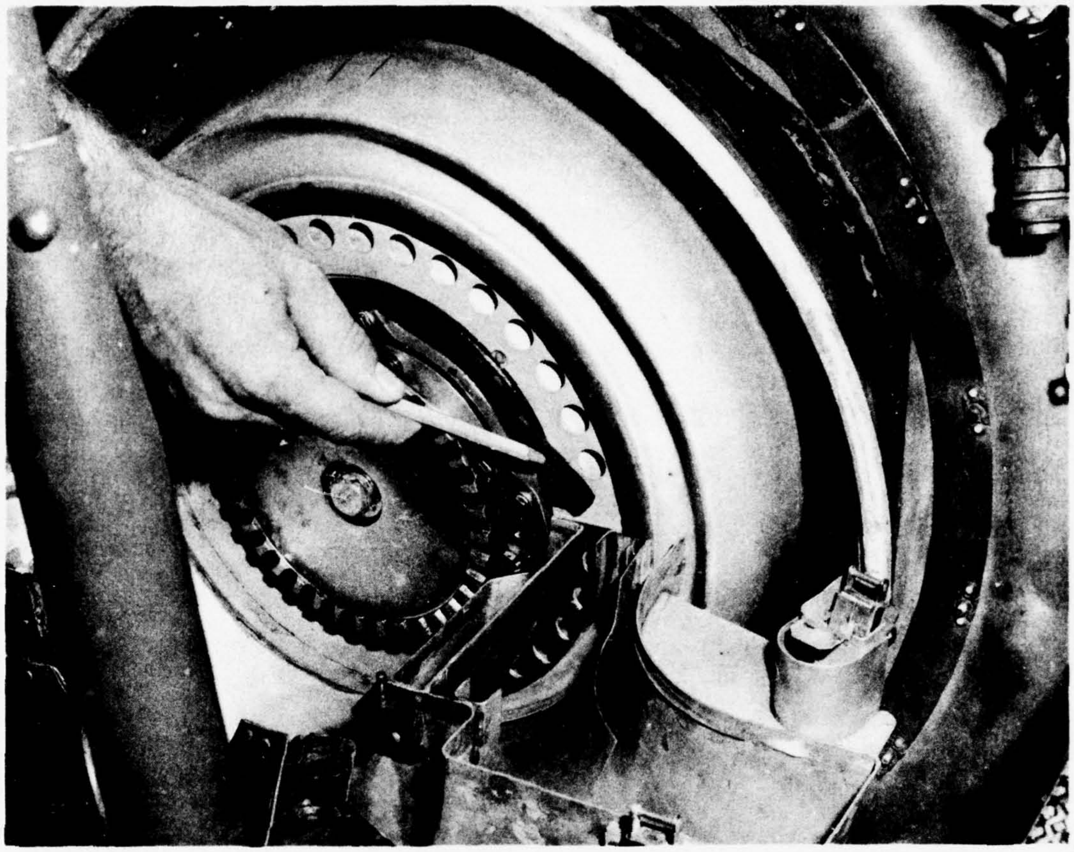


Figure 8. Adhesive failure of gasket attached to ring assembly.

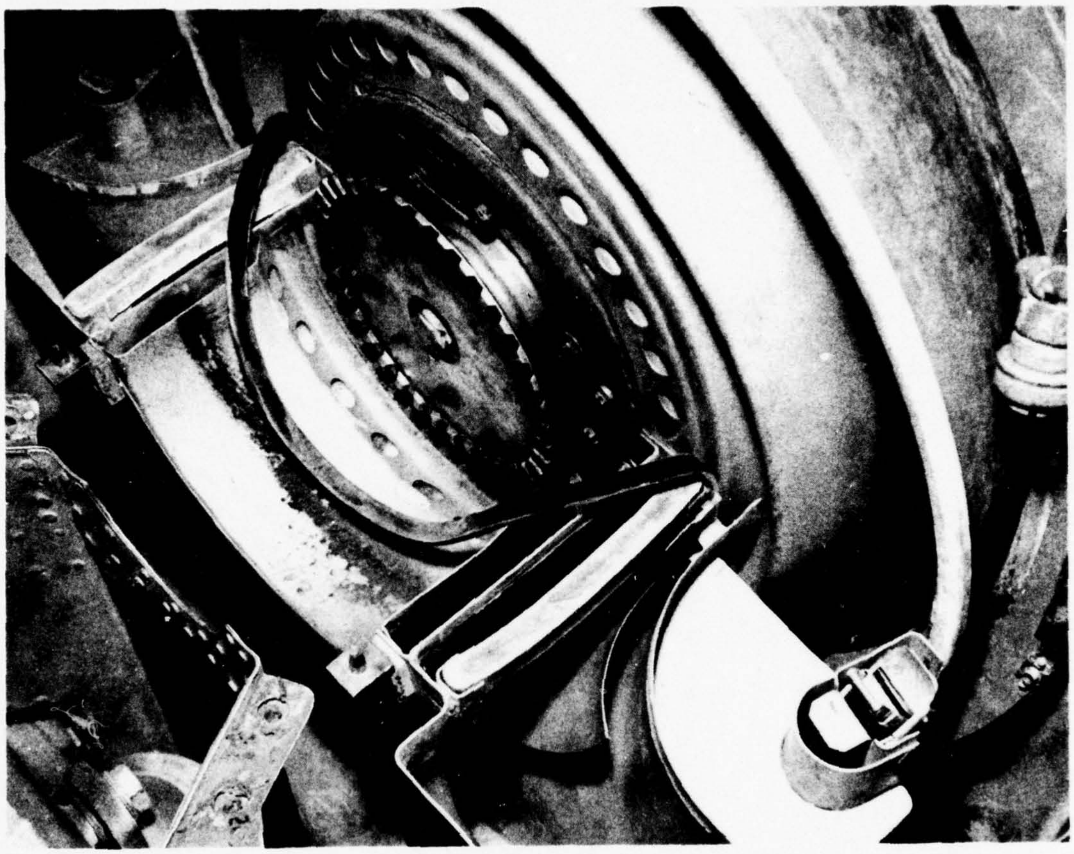


Figure 9. Adhesive failure of gasket attached to deflector assembly.

SECTION 3 - APPENDICES

APPENDIX I - TEST DATA

PART A

MANUFACTURER'S
INSTALLATION, INSPECTION, AND
MAINTENANCE PROCEDURES

AIR FILTER

PART NUMBER 1-010-500-06 FOR UH-1B HELICOPTER
PART NUMBER 1-010-500-05 FOR UH-1D HELICOPTER

SECTION I

INTRODUCTION

1.1 GENERAL.

1.2 This publication outlines procedures for installation and maintenance of the air filter used on Bell UH-1B and UH-1D helicopters.

1.3 The air filter is installed on the inlet housing of the shaft turbine engine.

1.4 The kit is packed and shipped with all parts and hardware in a single container.

1.5 MANUFACTURER.

1.6 The air filter is manufactured by Avco-Lycoming Division, Stratford, Connecticut, and is supplied as Air Filter Kit, part number 1-010-500-06, for UH-1B and 1-010-500-05 for UH-1D helicopters.

1.7 SPECIFICATIONS.

1.8 The air filter is 23.388 inches maximum diameter and 13.628 inches maximum length. Weight is approximately 24 pounds.

SECTION II

INSTALLATION

2.1 Expose inlet section of engine.

A. Remove baffle panels, screen, and bellmouth assemblies from helicopter. (Refer to TM55-1520-210-20 or TM55-1520-211-20, Chapter 5, Section III.) Keep V-band coupling loosely on inlet housing of engine.

NOTE: The screen and bellmouth assemblies will not be installed with the air filter.

B. Remove drive (short) shaft from engine and transmission. (Refer to TM55-1520-210-20 or TM55-1520-211-20, Chapter 7, Section II.)

C. Wipe inlet housing clean with cloth moistened with dry-cleaning solvent, Federal Specification P-D-680.

2.2 Position flange assembly (5, figure 2-1) on front of firewall and on inlet housing of engine. Retain assembly on firewall with screws, with thin washers under head, inserted from back of firewall. Do not tighten screws at this time. Retain flange assembly on inlet housing with V-band coupling (9). The flange assembly shall be left loose enough to be rotated.

2.3 Remove spacers (8), washers (7), and nuts (6) from studs on inlet housing. Discard washers, spacers, and nuts.

2.4 Position ring assembly (4) on studs of inlet housing. Observe that five studs on ring assembly are at the bottom with the center one at the six o'clock position. Secure assembly with spacers (10), washers (11), and nuts (12). Tighten nuts to 70 to 80 pound-inches torque.

CAUTION: Carefully install deflector assembly (3) to avoid cutting the rubber seal of ring assembly.

2.5 Position deflector assembly over studs of ring assembly and press in until firmly seated.

2.6 Position lower air filter assembly (14) on studs of ring assembly. Secure parts to ring assembly with washers (15) and nuts (16). Tighten nuts to 30 to 35 pound-inches torque.

2.7 Position upper air filter assembly (2) on lower air filter assembly.

<u>NOTE:</u> Do not install gasket assemblies (13 and 17) at this time.

2.8 Rotate flange assembly (5) on inlet housing to align receptacles with fasteners on filter assembly. Secure flange assembly with V-band coupling (9). Tighten coupling nut to 40 to 50 pound-inches torque. Tap around coupling from middle toward each end with a mallet to seat properly. Lockwire nut.

2.9 Tighten screws on firewall to secure flange assembly.

2.10 Remove upper air filter assembly.

<u>CAUTION:</u> Do not use oil or grease in tracks when installing filter assemblies.

2.11 Install screen filter assemblies (1) in upper and lower air filter assemblies with backing screen on the inside diameter. The filters should protrude equally from upper and lower air filter assemblies. If necessary, lubricate tracks with trichloroethylene, Federal Specification O-T-634.

2.12 Install baffle panels. (Refer to TM55-1520-210-20 or TM55-1520-211-20, Chapter 5, Section III.)

2.13 Install drive shaft between engine and transmission. (Refer to TM55-1520-210-20 or TM55-1520-211-20, Chapter 7, Section II.)

2.14 Install containers into lower air filter assembly.

2.15 Position gasket assemblies (13 and 17) over pins on lower air filter assembly.

2.16 Position upper air filter assembly on lower assembly. Tilt top part forward and place over locating pins first, then seat firmly with fasteners inserted into receptacles on flange assembly. Secure fasteners by turning 1/4 turn.

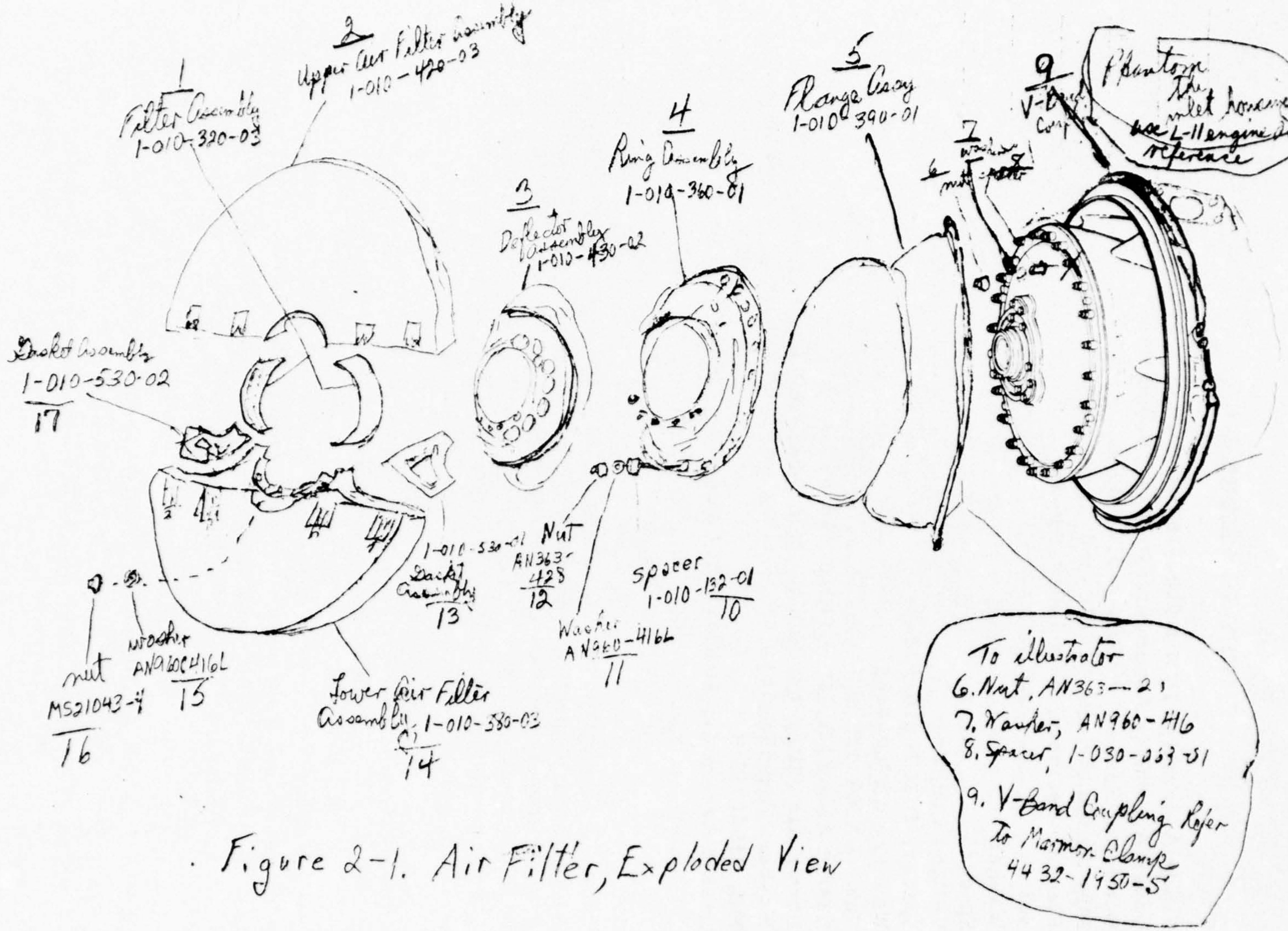


Figure 2-1. Air Filter, Exploded View

KEY TO FIGURE 2-1

1. Filter Assembly, P/N 1-010-320-03
2. Upper Air Filter Assembly, P/N 1-010-420-03
3. Deflector Assembly, P/N 1-010-430-02
4. Ring Assembly, P/N 1-010-360-01
5. Flange Assembly, P/N 1-010-390-01
6. Nut
7. Washer
8. Spacer
9. V-Band Coupling
10. Spacer, P/N 1-010-132-01
11. Washer, AN960-416L
12. Nut, AN363-428
13. Gasket Assembly, P/N 1-010-530-01
14. Lower Air Filter Assembly, P/N 1-010-380-03
15. Washer, AN960C416L
16. Nut, MS21043-4
17. Gasket Assembly, P/N 1-010-530-02

2.17 Engage locking catches on front face of filter assemblies and lock.

NOTE: Secure front catches first.

2.18 Engage locking catches at rear of filter assemblies and lock.

2.19 Observe for proper seating by appearance of seals. Approximately 1/8 inch of rubber on gasket assemblies will be exposed uniformly. Seal on flange assembly will be approximately half compressed.

SECTION III

CLEANING AND INSPECTION

3.1 FREQUENCY OF INSPECTION.

3.2 Inspection of the air filter will be accomplished following each day's mission until experience with local conditions indicate a change to this frequency.

3.3 Inspection will be accomplished following a day's mission when rain is encountered at any time during the day.

3.4 DISASSEMBLY FOR INSPECTION.

3.5 Release catches on front and rear faces of air filter assemblies (2 and 14, figure 2-1) by pulling up on locking tab and disconnect catch. Release fasteners from receptacles on flange assembly by backing off 1/4 turn. Remove upper air filter assembly.

3.6 Remove gasket assemblies (13 and 17).

3.7 Remove cannisters from lower air filter assembly. Use tab on cannister for finger hold.

CAUTION: When pulling filter assemblies, use hard rubber tab provided at each end.

3.8 Remove filter assemblies (1). Push on one end while pulling straight out at other end.

3.9 CLEANING AND INSPECTION.

3.10 Inspect gasket assemblies (13 and 17, figure 2-1) for rubber separation from backing plate and for cuts. Replace gasket assembly when rubber separation is severe. Repair cuts and minor separation. (Refer to paragraph 4.4.)

3.11 Empty cannisters of any accumulation of moisture and dirt. If water accumulation has overflowed the cannisters into well of lower air filter assembly, a cannister may be used to bail the assembly. Mud may be washed from cannisters and porous insert under running water. Shake dry.

3.12 Wipe out well of lower air filter assembly with clean cloth.

3.13 Shake filter assemblies (1) to remove loose dirt from screens. If necessary, wash in clear water and scrub with soft bristle fiber brush. Shake dry.

3.14 Inspect filter assemblies (1) for tears in screen. Replace assembly when tears exceed 1/8 inch. Repair minor tears and punctures. (Refer to paragraph 4.4.)

3.15 Inspect gasket on ring assembly (4) for cuts or looseness. Replace damaged areas with gasket tape.

3.16 Inspect gasket on deflector assembly (3) for cuts or looseness. Replace when badly damaged with gasket, P/N 1-010-186-01. Repair minor damage. (Refer to paragraph 4.4.)

3.17 Inspect for loose rivets or other damage in air filter assemblies (2 and 14). Tighten rivets as necessary.

3.18 REASSEMBLY.

3.19 Install parts. (Refer to paragraphs 2.11 and 2.14 thru 2.19.)

SECTION IV

MINOR REPAIRS

4.1 GENERAL

4.2 Repairs permissible on an installed assembly are limited to those of a minor nature.

4.3 REPAIRS.

4.4 Filter assemblies (1, figure 2-1) with tears not exceeding 1/8 inch, and loose gaskets on gasket assemblies (13 and 17), ring assembly (4), and deflector assembly (3) can become serviceable by applying compound, RTV (General Electric Co.) or equivalent, as necessary.

PART B

PARTS REPLACEMENT AND REPAIR ON PARTICLE SEPARATOR

UH-1D

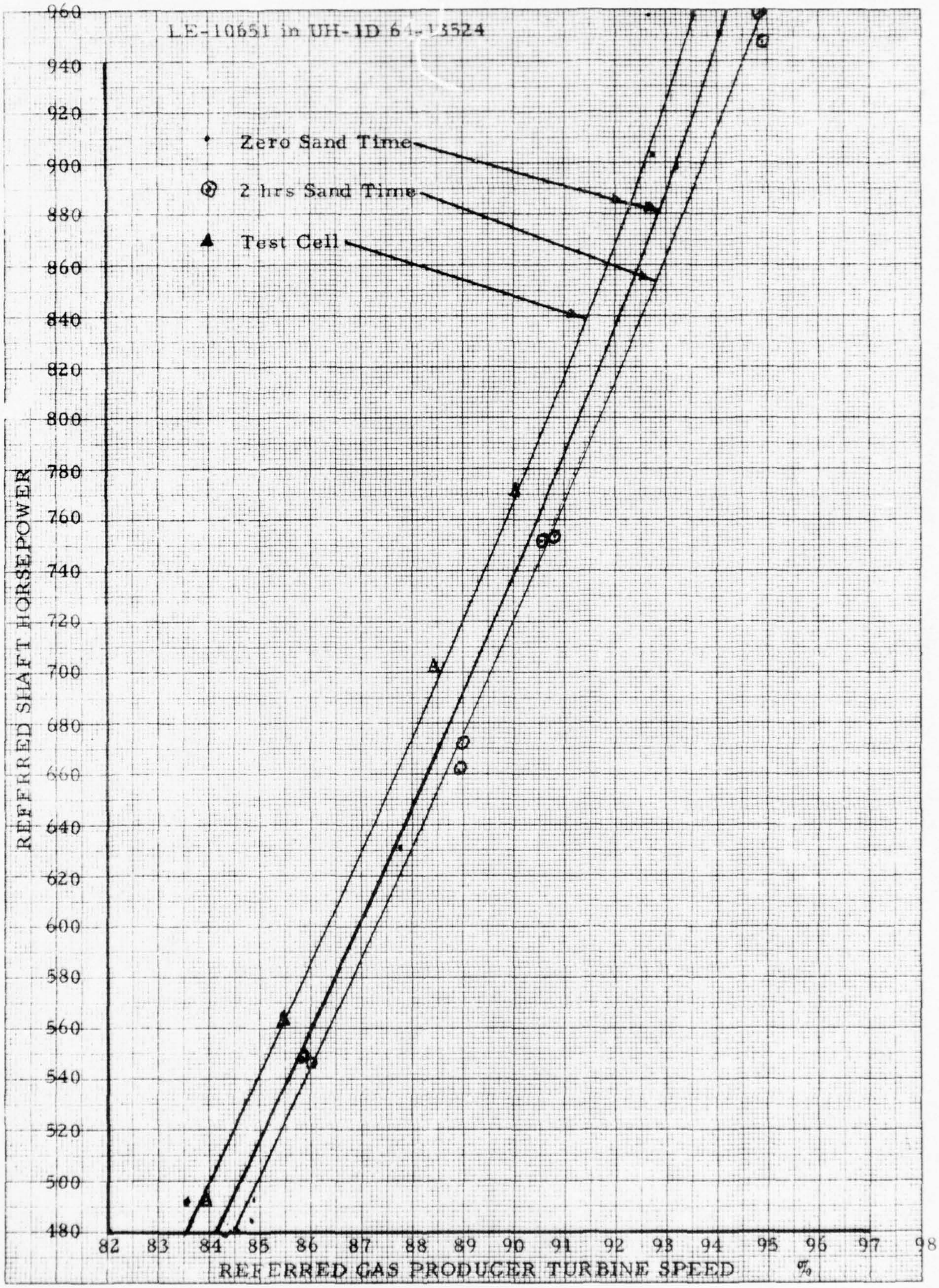
TEST HOURS	PARTS REPLACED	REASON FOR REMOVAL
17:20	Foam rubber gasket (attached to ring assembly).	Gasket loosened and deformed.
21:05	Foam rubber gasket (attached to ring assembly).	Gasket loosened and deformed.
21:05	Foam rubber gasket (attached to deflector assembly).	Gasket loosened and deformed.
24:55	Dzus fasteners on upper half of particle separator.	Dzus fasteners broken.
29:55	Foam rubber gasket (attached to deflector assembly).	Gasket loosened and deformed.
51:50	Foam rubber gasket (attached to deflector assembly).	Gasket loosened and deformed.

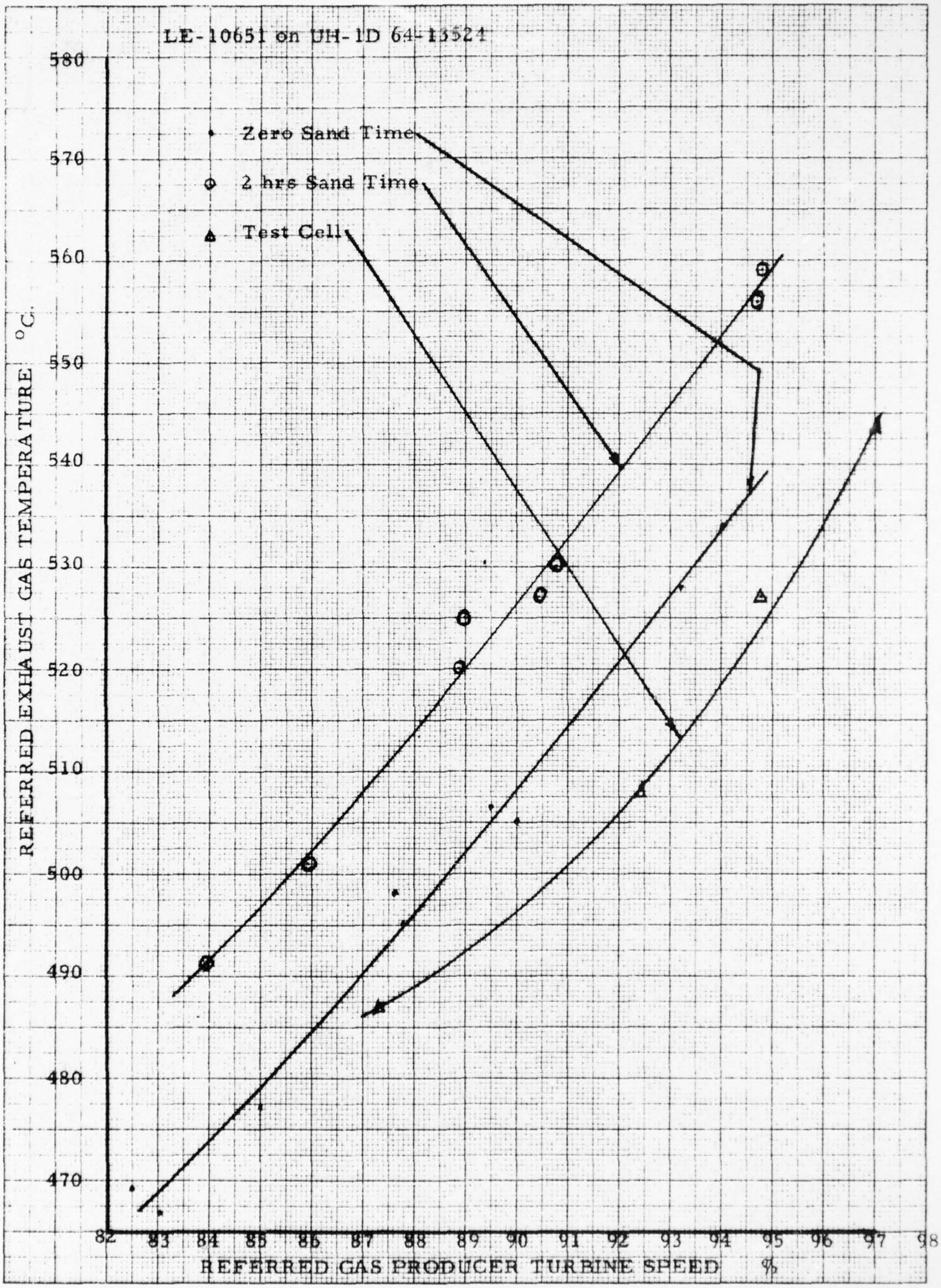
UH-1B

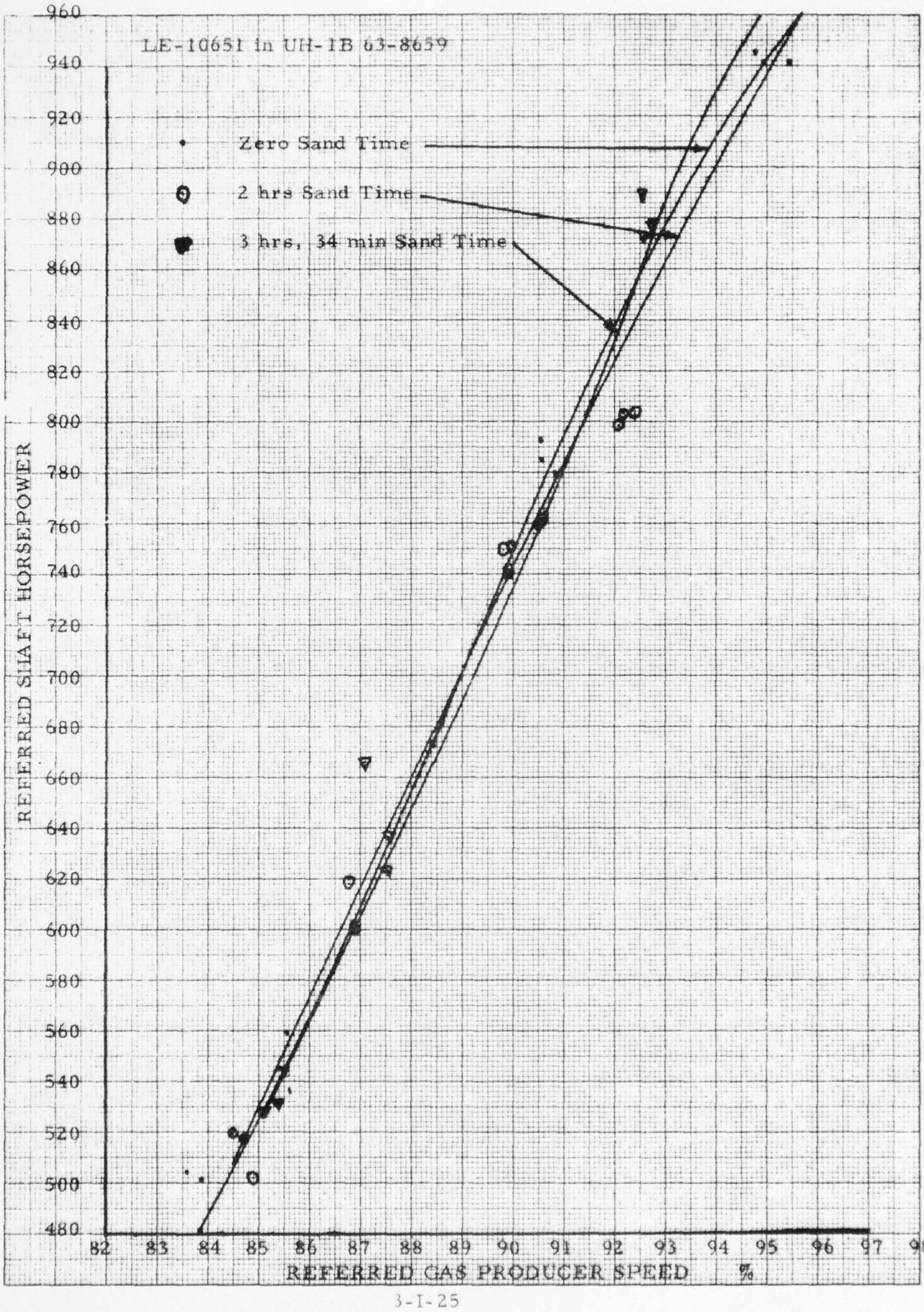
TEST HOURS	PARTS REPLACED	REASON FOR REMOVAL
12:05	Foam rubber gasket (attached to deflector assembly).	Gasket loosened and deformed.
14:45	Foam rubber gasket (attached to ring assembly).	Gasket loosened and deformed.

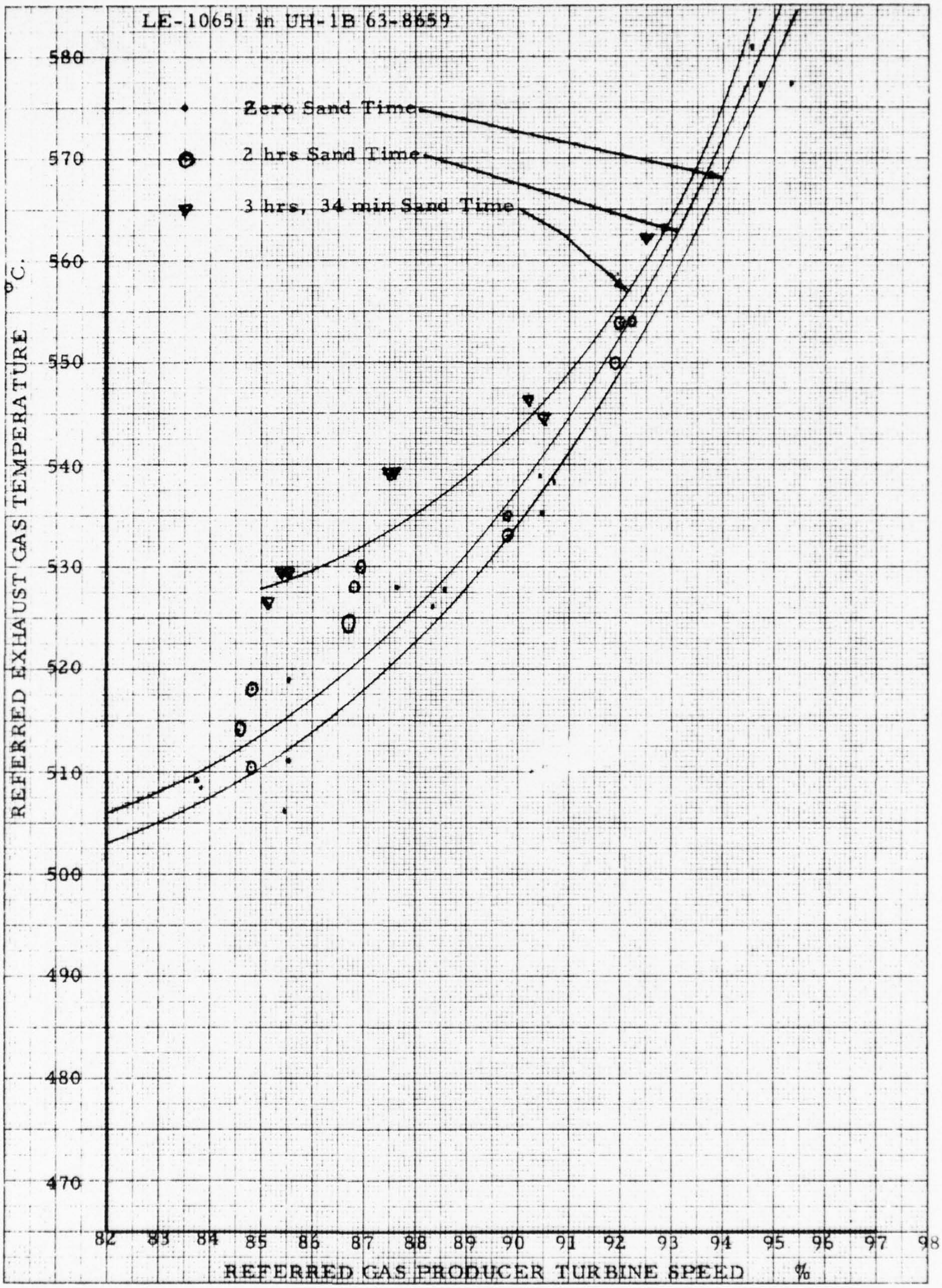
PART C

REFERRED ENGINE PERFORMANCE DATA


LE-10651 in UH-1D 64-13524
Zero Sand Time
2 hrs Sand Time
Test Cell
REFERRED SHAFT HORSEPOWER
960
940
920
900
880
860
840
820
800
780
760
740
720
700
680
660
640
620
600
580
560
540
520
500
480
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
REFERRED GAS PRODUCER TURBINE SPEED
%


LE-10651 on UH-1D 64-13524
Zero Sand Time
2 hrs Sand Time
Test Cell
REFERRED EXHAUST GAS TEMPERATURE °C.
580
570
560
550
540
530
520
510
500
490
480
470
82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
REFERRED GAS PRODUCER TURBINE SPEED %


LE-10651 in UH-1B 63-8659
Zero Sand Time
2 hrs Sand Time
3 hrs, 34 min Sand Time
REFERRED SHAFT HORSEPOWER
960
940
920
900
880
860
840
820
800
780
760
740
720
700
680
660
640
620
600
580
560
540
520
500
480
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
REFERRED GAS PRODUCER SPEED %



LE-10651 in UH-1B 63-8659
Zero Sand Time
2 hrs Sand Time
3 hrs, 34 min Sand Time
REFERRED EXHAUST GAS TEMPERATURE °C.
580
570
560
550
540
530
520
510
500
490
480
470
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
REFERRED GAS PRODUCER TURBINE SPEED %

1. The following data were derived from the engine performance curves:

	Referred Gas-Producer Turbine Speed		
	85%	88%	92%
Test Cell			
Referred shaft horsepower (s.hp.) on green run	541	674	868
UH-1D, 64-13524 (Particle Separator Installed)			
Referred s. hp. after installation	515	647	836
Loss of referred s. hp. due to installation	26	27	32
Percent loss of referred s. hp. due to installation	4.8	4.0	3.7
Referred s. hp. after 2 hr. of sand exposure	501	631	814
Loss of referred s. hp. after 2 hr. of sand exposure	14	16	22
Percent loss of referred s. hp. after 2 hr. of sand exposure	2.7	2.5	2.6
UH-1B, 63-8659 (Particle Separator Installed)			
Referred s. hp. after installation (2 hr. of total engine sand exposure)	525	654	838
Referred s. hp. after 2 hr. of sand exposure (4 hr. of total engine sand exposure)	*	*	*
Loss of referred s. hp. after 2 hr. of sand exposure (4 hr. of total engine sand exposure)	*	*	*
Percent loss of referred s. hp. after 2 hr. of sand exposure (4 hr. total engine sand exposure)	*	*	*
S. hp. after 3 hr. & 34 min. of sand exposure (5 hr. & 34 min. total engine sand exposure)	*	*	*
Loss of referred s. hp. after 3 hr. & 34 min. of sand exposure (5 hr. & 34 min. total engine sand exposure)	*	*	*
Percent loss of referred s. hp. after 3 hr. & 34 min. of sand exposure (5 hr. & 34 min. total engine sand exposure)	*	*	*
Test Cell			
Referred exhaust gas temperature in test cell on green run	Not Available	489°C.	506°C.

*Although three distinct lines appear on the referred s. hp. versus referred gas producer turbine speed performance graph for UH-1B 63-8659, analysis indicates no appreciable change in performance.

	Referred Gas-Producer Turbine Speed		
	85%	88%	92%
UH-1D, 64-13524 (Particle Separator Installed)			
Referred exhaust gas temperature after installation	479°C.	496°C.	521°C.
Increase in referred exhaust gas temperature due to installation	Not Available	7°C.	15°C.
Percent increase in referred exhaust gas temperature due to installation	Not Available	1.4	3.0
Referred exhaust gas temperature after 2 hr. of sand exposure	497°C.	514°C.	539°C.
Increase in referred exhaust gas temperature after 2 hr. of sand exposure	18°C.	18°C.	18°C.
Percent increase in referred exhaust gas temperature after 2 hr. of sand exposure	3.8	3.6	3.5
UH-1B, 638659 (Particle Separator Installed)			
Referred exhaust gas temperature after installation (2 hr. total sand exposure)	511°C.	523°C.	549°C.
Referred exhaust gas temperature after 2 hr. of sand exposure (4 hr. total sand exposure)	514°C.	526°C.	553°C.
Increase in referred exhaust gas temperature after 2 hr. of sand exposure (4 hr. total sand exposure)	3°C.	3°C.	4°C.
Percent increase in referred exhaust gas temperature after 2 hr. of sand exposure (4 hr. total sand exposure)	0.6	0.6	0.7
Referred exhaust gas temperature after 3 hr. & 34 min. of sand exposure (5 hr. & 34 min. total sand exposure)	528°C.	535°C.	556°C.
Increase in referred exhaust gas temperature after 3 hr. & 34 min. of sand exposure (5 hr. & 34 min. total sand exposure)	17°C.	12°C.	7°C.
Percent increase in referred exhaust gas temperature after 3 hr. & 34 min. of sand exposure (5 hr. & 34 min. total sand exposure)	3.3	2.3	1.3

2. It should be noted that the validity of the Referred Exhaust Gas Temperature Graphs for UH-1B 63-8659 are somewhat compromised by the degree of data scatter present. The general trend toward higher exhaust gas temperature with no appreciable shaft horsepower change can, however, be considered valid.

PART D

ENGINE COMPRESSOR BLADE WEIGHT COMPARISON

AND ENGINE MEASUREMENTS

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ENGINE COMPRESSOR BLADE WEIGHT COMPARISON

Stage	Position (°)	Start (grams)	Two Hours' Sand Time (grams)	Change (percent)	Four Hours' Sand Time (grams)	Change (percent)
First	0	20.9	20.1	-3.83	20.0	-4.30
	180	21.1	20.3	-3.78	20.2	-4.25
Second	0	15.7	15.1	-3.82	14.9	-5.10
	180	15.8	15.1	-4.43	14.9	-5.70
Third	0	10.8	10.5	-2.78	10.4	-3.70
	180	10.8	10.5	-2.78	10.4	-3.70
Fourth	0	9.7	9.4	-3.10	9.3	-4.12
	180	9.7	9.4	-3.10	9.3	-4.12
Fifth	0	9.1	8.8	-3.30	8.6	-5.50
	180	9.1	8.8	-3.30	8.6	-5.50

AXIAL COMPRESSOR RADIAL TIP CLEARANCES

Stage	Start (in.) Right	Start (in.) Left	Two Hours' Sand Time Right	Two Hours' Sand Time Left	Change (percent) Right	Change (percent) Left	Four Hours' Sand Time Right	Four Hours' Sand Time Left	Change (percent) Right	Change (percent) Left
Top Half										
First	0.025	0.028	0.033	0.032	32.0	14.3	0.035	0.033	40.0	17.8
Second	0.024	0.028	0.035	0.031	45.8	10.7	0.033	0.030	37.5	7.2
Third	0.024	0.026	0.036	0.028	50.0	7.7	0.035	0.030	45.7	15.4
Fourth	0.026	0.028	0.037	0.028	42.3	0.0	0.037	0.033	42.2	17.9
Fifth	0.026	0.028	0.038	0.028	46.1	0.0	0.034	0.034	30.7	21.5
Bottom Half										
First	0.026	0.029	0.032	0.032	23.0	10.3	0.035	0.035	34.6	20.6
Second	0.026	0.026	0.032	0.031	23.0	19.2	0.032	0.032	23.0	23.0
Third	0.024	0.024	0.035	0.028	45.8	16.7	0.033	0.027	37.5	12.5
Fourth	0.026	0.024	0.037	0.028	42.3	16.7	0.036	0.027	38.5	12.5
Fifth	0.026	0.024	0.037	0.031	42.3	29.1	0.039	0.028	50.0	14.3

N_1 TURBINE TIP CLEARANCES

Clock Position	Start (in.)	Two Hours' Sand Time (in.)	Change (percent)	Four Hours' Sand Time (in.)	Change (percent)
1200	0.030	0.035	16.7	0.034	13.30
0130	0.029	0.032	10.3	0.030	3.45
0300	0.026	0.032	23.0	0.030	15.40
0430	0.026	0.033	27.0	0.032	23.00
0600	0.030	0.036	20.0	0.034	13.30
0730	0.030	0.036	20.0	0.038	26.60
0900	0.034	0.038	11.8	0.044	29.50
1030	0.030	0.036	20.0	0.038	26.60

CENTRIFUGAL COMPRESSOR CLEARANCES

Top Half

Measurement	Start (in.)		Two Hours' Sand Time		Change (percent)		Four Hours' Sand Time		Change (percent)	
Point	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
1	0.024	0.025	0.026	0.022	8.3	12.0	0.025	0.025	4.16	0.00
2	0.025	0.026	0.030	0.026	20.0	0.0	0.026	0.027	4.00	3.85
3	0.035	0.030	0.041	0.034	17.2	13.3	0.058	0.051	65.80	70.00
4	0.036	0.036	0.032	0.032	11.1	11.1	0.035	0.036	2.75	0.00
Bottom Half										
1	0.020	0.017	0.040	0.019	100.0	11.8	0.026	0.020	30.00	17.60
2	0.020	0.025	0.035	0.032	75.0	28.0	0.027	0.038	35.00	52.00
3	0.025	0.027	0.020	0.048	-25.0	78.0	0.038	0.042	52.00	55.60
4	0.042	0.036	----	----	----	----	0.046	0.035	9.50	2.78

PART E

EROSION EFFECTS ON ENGINE COMPRESSOR COMPONENTS

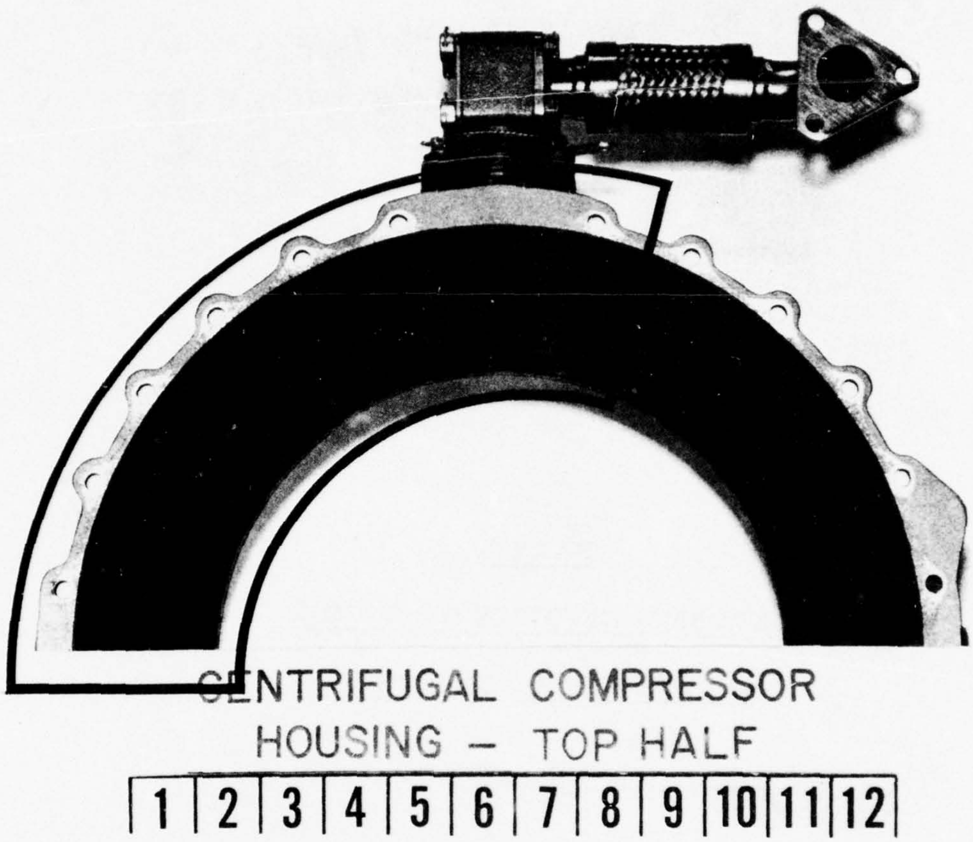

Figure E-1. Compressor housing prior to test. Area outlined is shown in figure E-2.

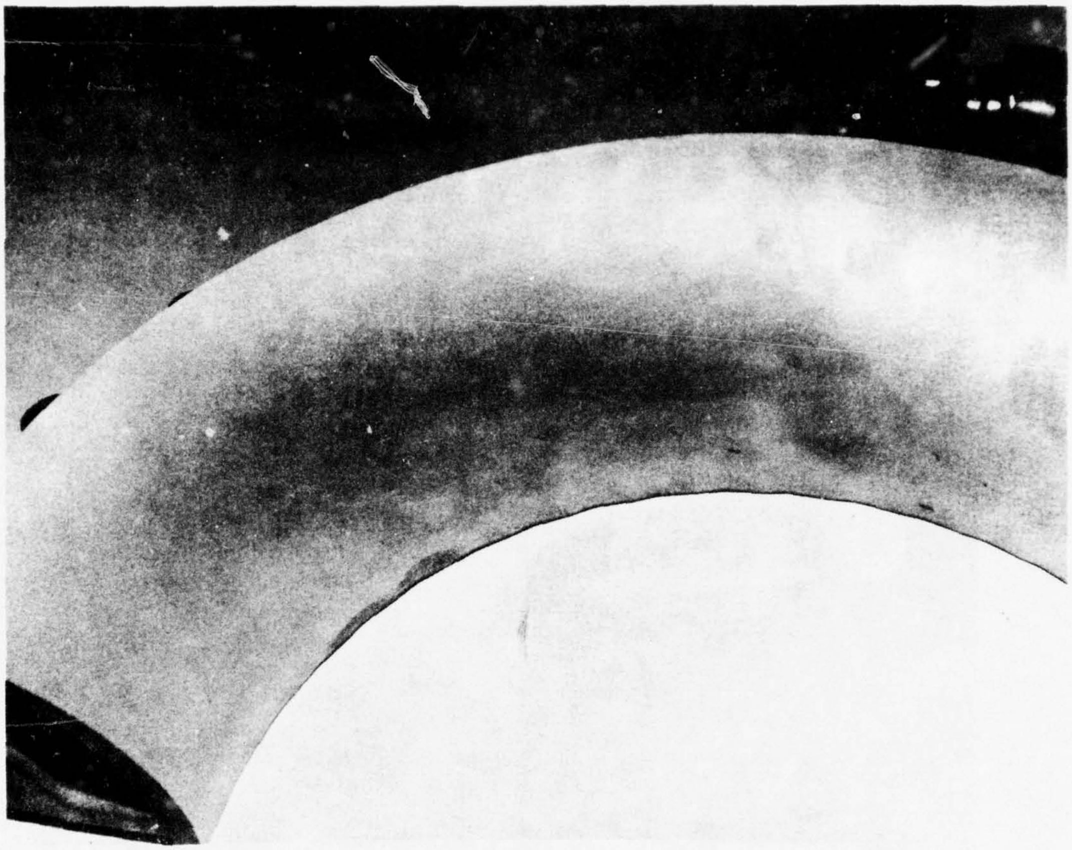

Figure E-2. Compressor housing erosion pattern in vicinity of discharge from axial compressor after 5.6 hours' sand exposure.

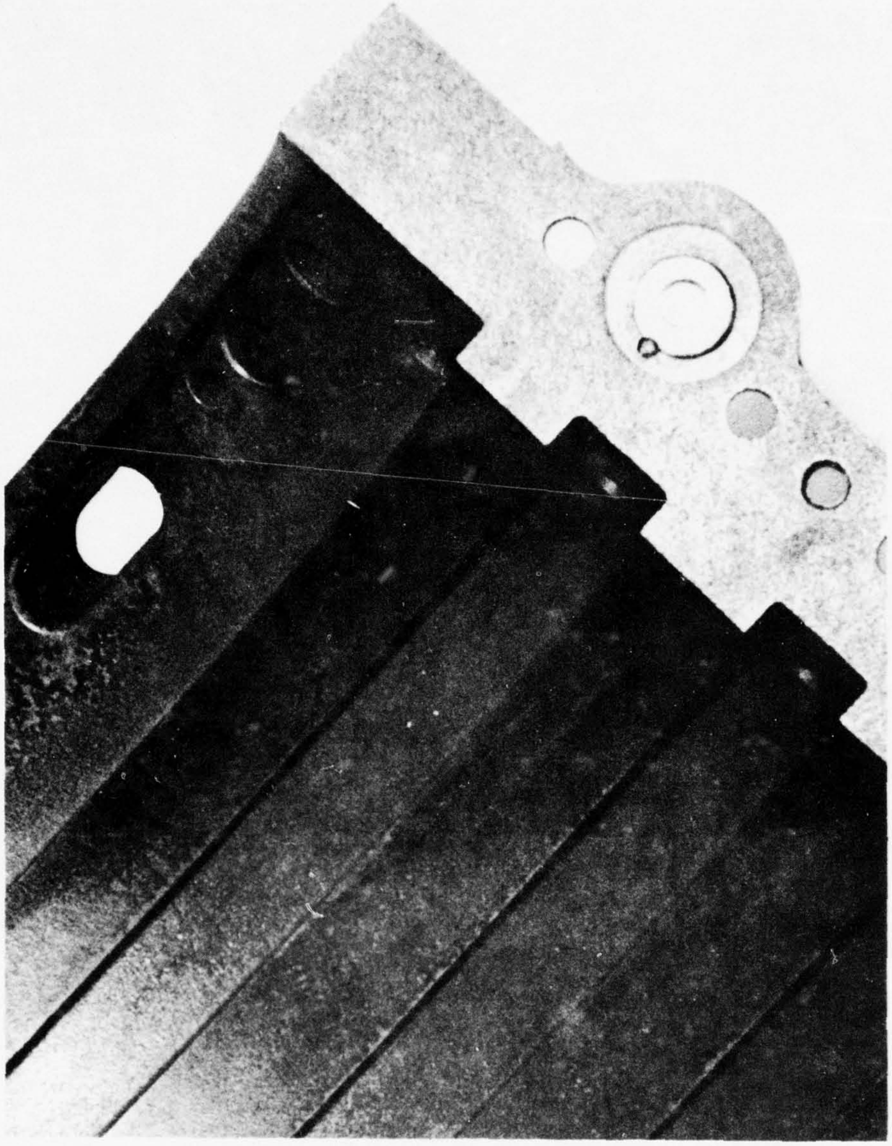

Figure E-3. Compressor case prior to test. Area outlined is shown in figure E-4.

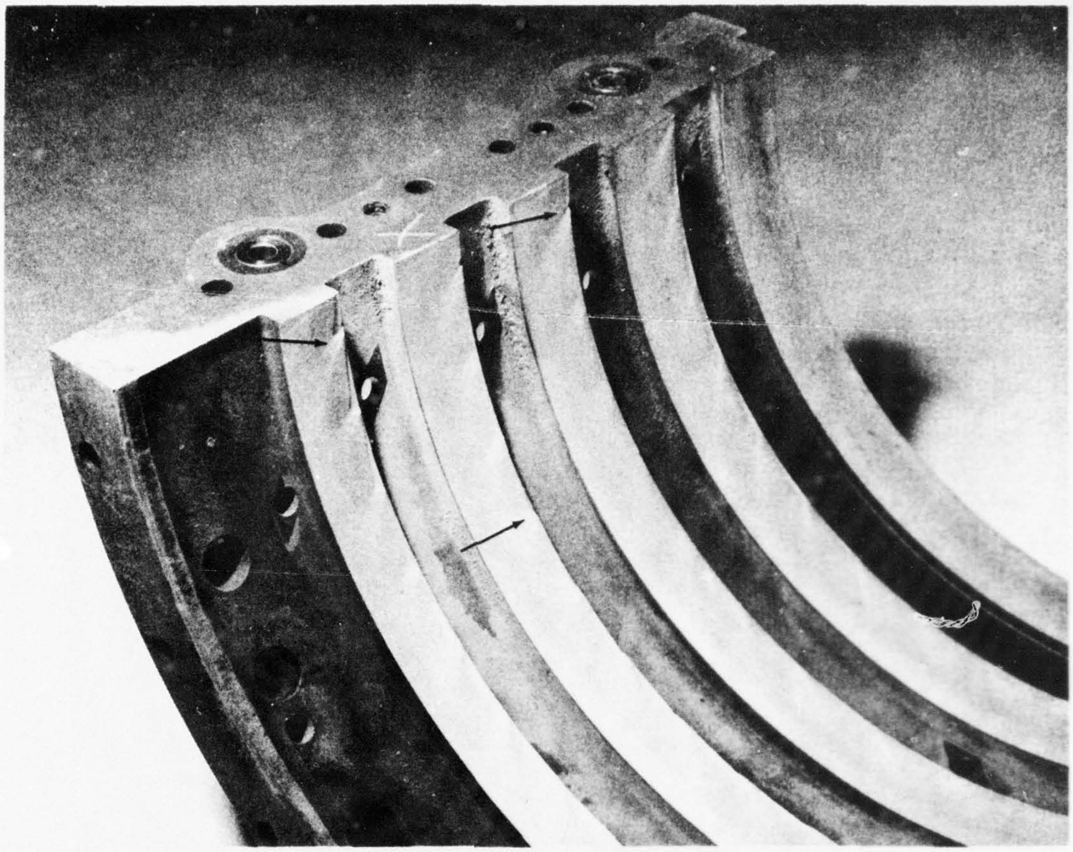

Figure E-4. Upper half of compressor case after 5.6 hours' sand time. Arrows indicate areas of greatest erosion.

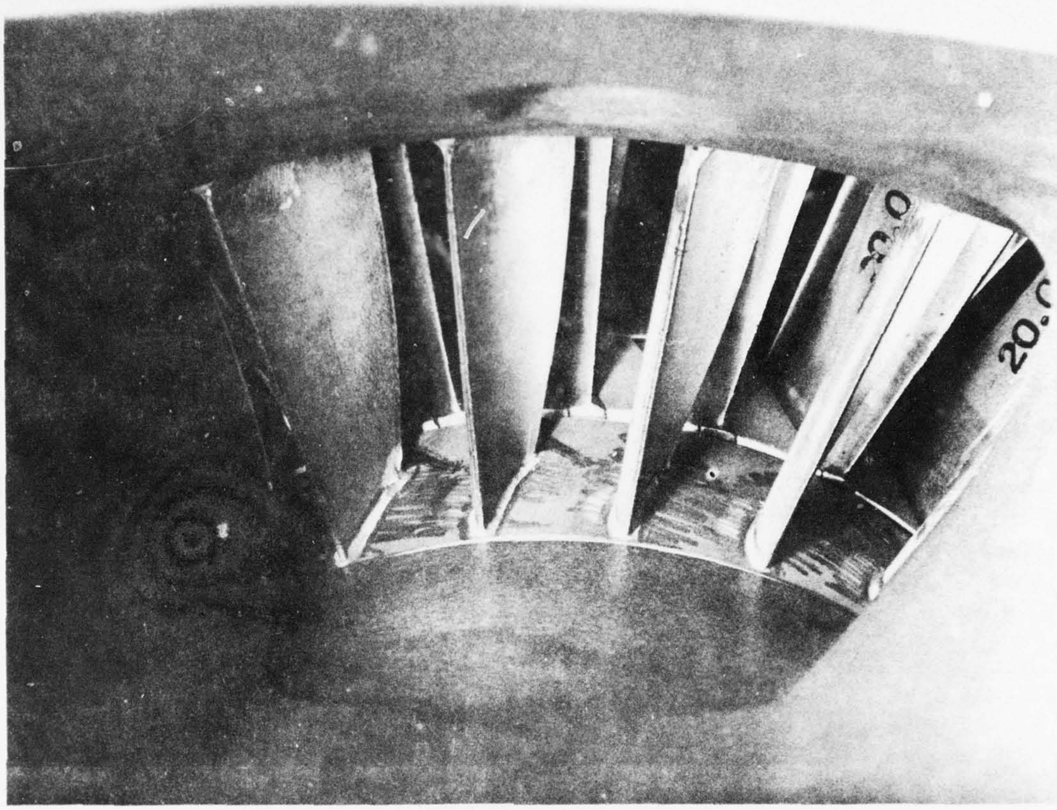

Figure E-5. Inlet guide vanes and first-stage rotor blade prior to test. Note the rough texture of metal surface.

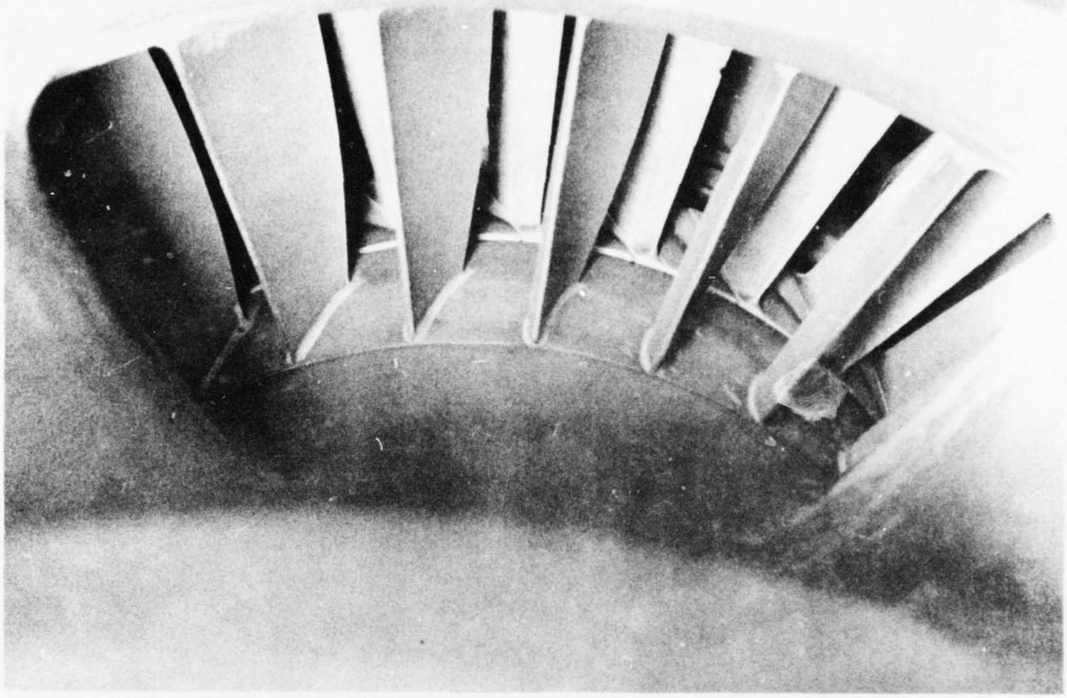

Figure E-6. Inlet guide vanes and first-stage rotor blade after 5.6 hours' sand exposure. Note slight FOD on blade and the smooth, more even surface of the vanes.

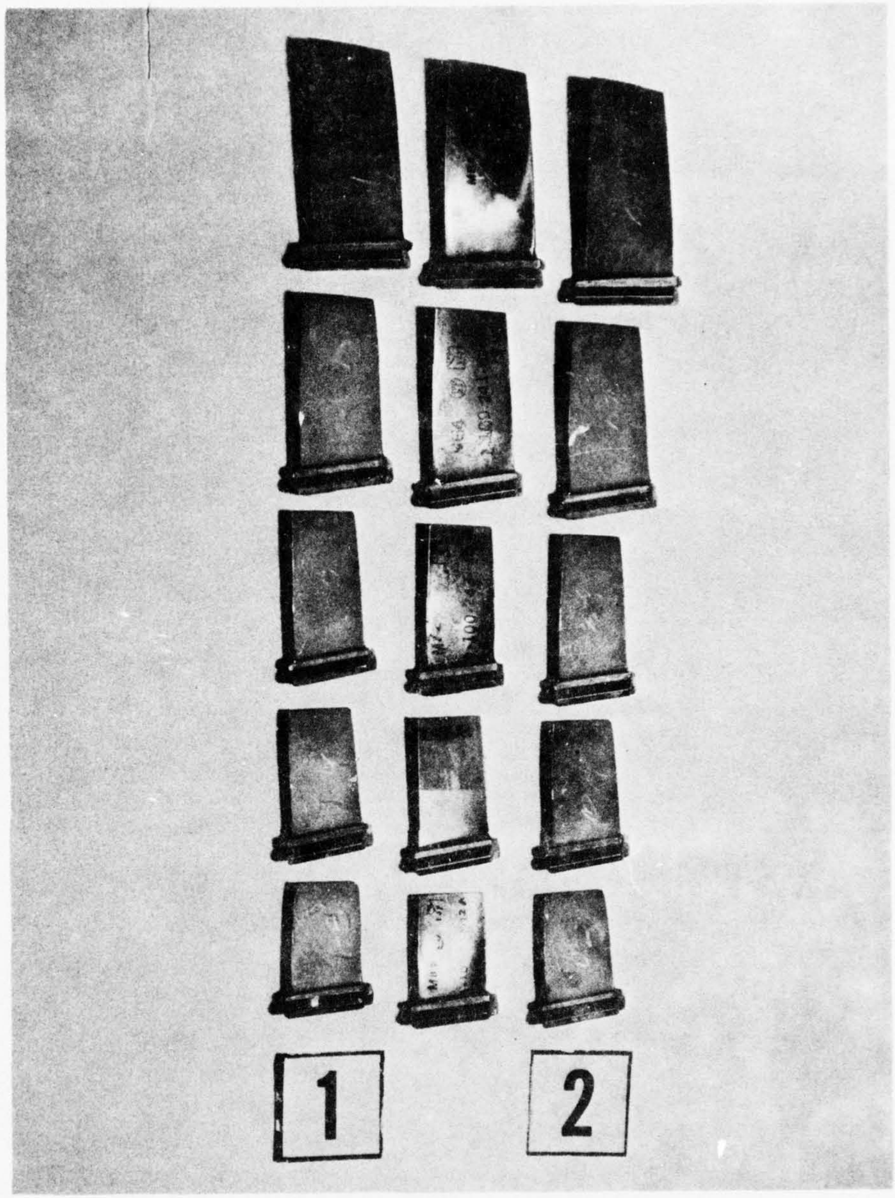

Figure E-7. Suction side of compressor rotor blades, first through fifth stage (top to bottom) after 5.6 hours' sand exposure with separator installed. Note new blades in center for comparison.

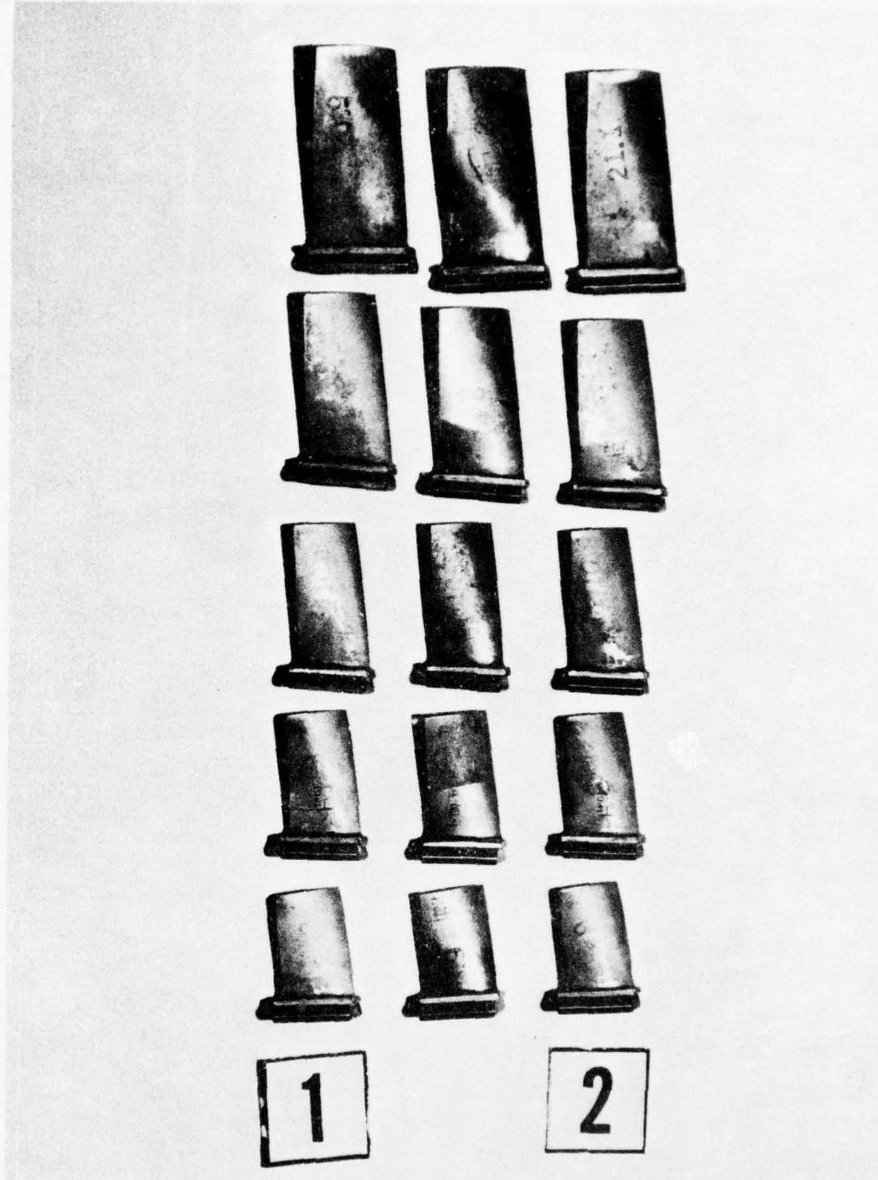

Figure E-8. Pressure side of compressor rotor blades after 5.6 hours' sand exposure with separator installed.

APPENDIX II - DEFICIENCIES AND SHORTCOMINGS

1. <u>Deficiencies</u>. The following deficiencies were discovered:

Deficiency	Suggested Corrective Action	Remarks
a. There were no deicing or anti-icing provisions for either the particle separator or the external screen assembly.	None.	This deficiency was previously reported in reference 3, appendix III.
b. There was no provision for warning of ice formation or to bypass a clogged internal screen assembly.	Provide an automatic alternate air source with a manual backup.	This deficiency was previously reported in reference 3, appendix III.
c. The adhesives used to secure the rubber gaskets to the metal surfaces were unsatisfactory.	Use adhesives resistant to MIL-7808E lubricating oil and MIL-5606 hydraulic fluid.	The gaskets required frequent replacement and caused excessive maintenance.
d. An MWO was not provided with the test item.	None.	The manufacturer's draft installation and maintenance instructions were not adequate for further dissemination.

2. <u>Shortcomings</u>. The following shortcomings were discovered:

Shortcoming	Suggested Corrective Action	Remarks
a. After exposure to moisture, mud formed on the internal particle	None.	This shortcoming was previously reported in

Shortcoming	Suggested Corrective Action	Remarks
separator screens, rendering the device inoperative until the screens were cleaned.		reference 3, appendix III.
b. The particle separator contributed to the high short-shaft temperatures encountered on the UH-1D Helicopter.	Provide additional ventilation in the vicinity of the short shaft.	This condition occurred only on the UH-1D Helicopter, and further study using quantitative methods should be made.

APPENDIX III - REFERENCES

1. Minutes of Iroquois UH-1 Particle Separator and Screen Conference, US Army Aviation Materiel Command (USAAVCOM), 29 March 1966.

2. Letter, SMOSM-EAA, Headquarters, US Army Aviation Materiel Command, 29 April 1966, subject: "Request for Test Directive for Phase E and Phase F Test of the Lycoming Particle Separator and Inlet Screen."

3. Report of Test, USATECOM Project No. 4-3-0150-16, "Product Improvement Test (Comparative Evaluation) of the T53-L-11 Engine Inlet-Air Barrier Filter and Particle Separator," US Army Aviation Test Board, 15 June 1966.

4. Letter, Bell Helicopter Company, 24 June 1966, subject: "Results of Lycoming Particle Separator Tests on a UH-1B Helicopter."

5. Inter Office Memo, Bell Helicopter Company, 27 June 1966, subject: "Power Loss with Lycoming Particle Separator and Bell Fine Mesh Screen Installed on UH-1D Helicopter."

6. Final Report of Test, USATECOM Project No. 4-4-0108-04, "Product Improvement Test of the UH-1B Helicopter Equipped with the Model 540 Rotor System," US Army Aviation Test Board, 22 July 1966.

7. Plan of Test, USATECOM Project No. 4-6-0105-01, "Product Improvement Test of Prototype Universal Particle Separator," US Army Aviation Test Board, 30 September 1966.

8. Report of Test, USATECOM Project No. 4-4-0108-10, "Product Improvement Test (Desert Environment CY 66) of UH-1B/540 Helicopter," US Army Aviation Test Board, 4 October 1966.

APPENDIX IV - DISTRIBUTION

Agency	Final Report
Commanding General US Army Test and Evaluation Command ATTN: AMSTE-BG Aberdeen Proving Ground, Maryland 21005	2
Commanding General US Army Materiel Command ATTN: AMCPM-IR-T Washington, D.C. 20315	5
Director Iroquois Field Office ATTN: AMCPM-IRFO-T P.O. Box 209, Main Office St. Louis, Missouri 63166	5
Lycoming Company ATTN: Dallas Grimes Stratford, Connecticut	1
Bell Helicopter Company P.O. Box 482 ATTN: Charles Moore Fort Worth, Texas 76101	1

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) US Army Aviation Test Board Fort Rucker, Alabama	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

"PRODUCT-IMPROVEMENT TEST OF THE PROTOTYPE UNIVERSAL UH-1( ) PARTICLE SEPARATOR (PHASE I)"

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report of Test, 5 July 1966 to 16 December 1966

5. AUTHOR(S) (Last name, first name, initial)

SZCZEPANSKI, Richard D., CW2

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
May 1967	81	8

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	USATECOM PROJECT NO. 4-6-0105-01

10. AVAILABILITY/LIMITATION NOTICES

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	US Army Materiel Command Washington, D.C. 20315

13. ABSTRACT The US Army Aviation Test Board tested the Prototype Universal UH-1( ) Particle Separator installed in UH-1B and UH-1D Helicopters at Fort Rucker, Alabama, from 5 July 1966 to 16 December 1966. The particle separator installed in the UH-1C Helicopter was tested at Yuma, Arizona, from 18 to 27 July 1966. Testing was conducted to obtain operational experience relative to the suitability of the separator. The flight program for the UH-1B and UH-1D included hovering the helicopters in the same sandy area used in previous tests and operating the separator under field conditions such as those encountered in the Republic of Vietnam; whereas, the separator installed in the UH-1C was operated only in a sandy environment. Four deficiencies and two shortcomings were found during the test. The deficiencies were the lack of a Modification Work Order, deicing or anti-icing provisions, ice formation warning provision, and unsatisfactory adhesives for securing the rubber gaskets to metal surfaces. It was concluded that correction of the shortcomings would enhance the suitability of the particle separator and that after correction of the deficiencies, the particle separator should be suitable for Army use. It was recommended that the shortcomings be corrected as technically and economically feasible, that the separator be adopted for use on all UH-1( ) helicopters after correction of the deficiencies, and that further testing, using quantitative methods, be conducted to determine the effects of the particle separator installed in the UH-1D on short-shaft operating temperatures. (U)

14. KEY WORDS		LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Product improvement test	Rain ingestion						
Prototype Universal UH-1( ) Particle Separator	Engine output shaft seal						
UH-1B Helicopter	Cleaning and servicing						
UH-1C Helicopter	Maintenance requirements						
UH-1D Helicopter	Erosion						
US Army Aviation Test Board	Sand and dust						
Fort Rucker, Alabama	Deficiencies						
Yuma Proving Ground, Arizona	Shortcomings						
Draft Modification Work Order							
Installation requirements							
Draft maintenance instructions							
Performance							
Drive shaft operating temperature							

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